ARGONNE NATIONAL LABORATORY-EAST

Investigation Report

Building 34 – Liquid Mixed Waste Treatment
SWMU No. 150

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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document. Acronyms and abbreviations used only in the tables and figures are defined in the respective table and figure captions.

Acronyms, Initialisms, and Abbreviations

ACL	Analytical Chemistry Laboratory
amsl	above mean sea level
ANL-E	Argonne National Laboratory – East
APS	Advanced Photon Source
ASTM	American Society for Testing Materials
bgs	below ground surface
BNA	base-neutral-acid
CLP	Contract Laboratory Program
CME	Central Mine Equipment
DOE	U.S. Department of Energy
DQO	data quality objective
ENE	East-Northeast Area
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
GRO	groundwater remediation objective
IAC	Illinois Administrative Code
IEPA	Illinois Environmental Protection Agency
LCS	laboratory control spike
LCSD	laboratory control spike duplicate
LMWTF	Liquid Mixed Waste Treatment Plant
MS/MSD	matrix spike/matrix spike duplicate
NFA	No Further Action
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
PCB	polychlorinated biphenyl
PQL	practical quantitation limit
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
QA/QC	quality assurance/quality control
QL	quantitation limit
SRO	soil remediation objective
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TACO	Tiered Approach to Corrective Action Objectives
TCMX	tetrachloro-m-xylene
TIC	tentatively identified compound

TOC	total organic compound
TOX	total organic halogen
USCS	Unified Soil Classification System
UTL	upper tolerance limit
VOC	volatile organic compound
ybp	years before present

Units of Measure

ºC	degree(s) Celcius
ºF	degree(s) Farenheit
cm	centimeter(s)
d	day(s)
ft	foot (feet)
ft^2	square foot (feet)
g	gram(s)
gal	gallon(s)
h	hour(s)
in.	inch(es)
kg	kilogram(s)
L	liter(s)
mg	milligram(s)
mi	mile(s)
min	minute(s)
pCi	picoCurie(s)
s	second(s)
µg	microgram(s)
µmhos	microohmos
yd^3	cubic yard(s)

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1 INTRODUCTION

The U.S. Department of Energy (DOE) and Argonne National Laboratory-East (ANL-E) are currently conducting corrective action activities associated with numerous solid waste management units (SWMUs) located at the ANL-E site. This investigation report focuses on the Building 34 – Liquid Mixed Waste Treatment (SWMU No. 150) and describes the more detailed characterization actions undertaken to determine the nature and extent of associated soil and groundwater contamination and to allow comparison with established remediation objectives.

In accordance with Section V.C. of the ANL-E Resource Conservation and Recovery Act (RCRA) Part B Permit, "Conducting SWMU Investigations," a work plan for this SWMU was prepared by ANL-E and approved by the Illinois Environmental Protection Agency (IEPA) prior to conducting any investigative efforts. The Work Plan, entitled *Investigation Work Plan, Building 34 – Liquid Mixed Waste Treatment, SWMU No. 150*, was submitted to IEPA in October 1998 and approved on October 13, 1999 (Munie 1999). A field investigation was conducted from November 1999 through January 2001, according to the approved Work Plan. This investigation report presents the final results of the investigative efforts for this unit. As described in this report, the results of the soil and groundwater sampling demonstrated that groundwater contamination in excess of IEPA Tier 1 groundwater remediation objectives (GROs) is present in the vicinity of SWMU No. 150. Consequently, ANL-E proposes to conduct corrective action activities pursuant to Section V.D. and Attachment C-3 of ANL-E's RCRA Part B permit, which was approved on September 30, 1997.

Two certification statements are included in Appendix A, in accordance with the requirements of Title 35, Part 702.126 of the *Illinois Administrative Code* (35 IAC 702.126). The first is signed by DOE and ANL-E authorized representatives and a licensed professional engineer. The second is signed by a responsible officer of the analytical laboratory that conducted the chemical and radiological analyses and certifies that U.S. Environmental Protection Agency (EPA) SW-846 methods were followed during the chemical analysis of all samples (EPA 1986).

This investigation report contains sampling data for the radioactive materials for SWMU No. 150. Radioactive materials at facilities owned by DOE are under the jurisdiction of DOE rather than IEPA. Nevertheless, the radiological data are included for completeness and to ensure that all potentially hazardous materials are addressed, regardless of regulatory circumstances.

1.1 DESCRIPTION OF ARGONNE NATIONAL LABORATORY-EAST

ANL-E is a Government-owned research and development facility operated by the University of Chicago under contract with DOE. As shown in Figure 1.1, ANL-E is located in southern DuPage County, Illinois, approximately 27 mi southwest of the City of Chicago. The ANL-E facility occupies about 1,500 acres of land in Township 37 North, Range 11 East, Sections 3, 4, 8, 9, 10, 15, 16, and 17. The facility is surrounded on all sides by the 2,240-acre Waterfall Glen Forest Preserve. The preserve is bounded on the north by Interstate Highway 55, on the south by the Des Plaines River, on the east by Cass Avenue, and on the west by Lemont Road. Within the site, about 15% of the land is used for laboratory and support facilities; the remaining land consists of forest and landscape areas.

ANL-E has been a center for research and development of the beneficial uses of nuclear energy since its inception. More recently, physical and biological research have also been incorporated into its activities. The Standard Industrial Code for ANL-E is 8733, “Non-Commercial Research.”

1.2 SITE DESCRIPTION

Building 34 and the adjacent property served as the Liquid Mixed Waste Treatment Plant (LMWTP) from the late 1940s until 1978. The LMWTP, located in the East Area of the ANL-E facility (see Figure 1.2), consisted of one building (Building 34), three in-ground concrete tanks, and associated piping for chemical neutralization and reaction treatment of radioactive liquids containing acids, metals, and solvents.

One tank, measuring about 12 ft by 20 ft, was located on the north side of the building and was used to treat liquid cyanide waste. Two additional tanks, measuring about 6 ft by 8 ft and 12 ft by 14 ft, were located on the west side of the building and were used to treat metals and acids, respectively. The tank depths extended to approximately 12 to 15 ft below grade. Acids were neutralized with sodium hydroxide, cyanides were oxidized with chlorine in alkaline solution to form cyanates, chromium was reduced by means of sulfur dioxide, and uranium was precipitated as the hydroxide. The tanks were also used to accumulate waste pending treatment.

The unit encompassed about 600 ft^2. The LMWTP facilities were demolished in the 1980s. The entire building and the in-ground concrete tanks were removed. During demolition, ANL discovered that the underground piping had leaked contaminated wastewater to the soil. The most likely contaminants released to the soil were radioactive materials from scrubber wastewater, which originated in the air cleaning system of the radioactive materials machine shop, and acids from pickling and plating tanks. About 90 yd^3 of soil was excavated and shipped off-site to a DOE radioactive waste disposal facility. Remaining soils were not sampled for hazardous constituents; rather, radioactive contamination was removed to about background levels of 20 pCi/g (ANL 1994).

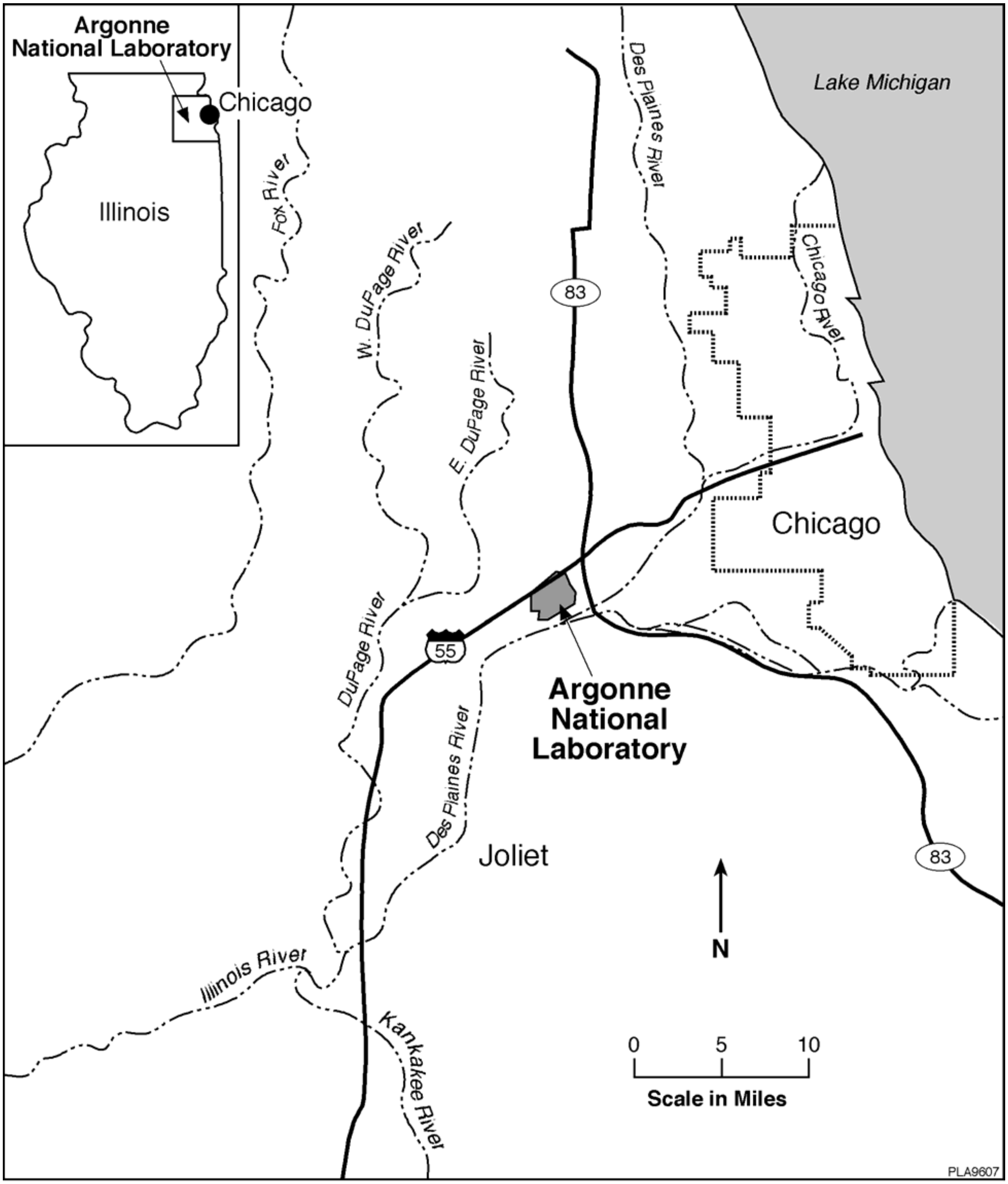


FIGURE 1.1 Location of Argonne National Laboratory-East

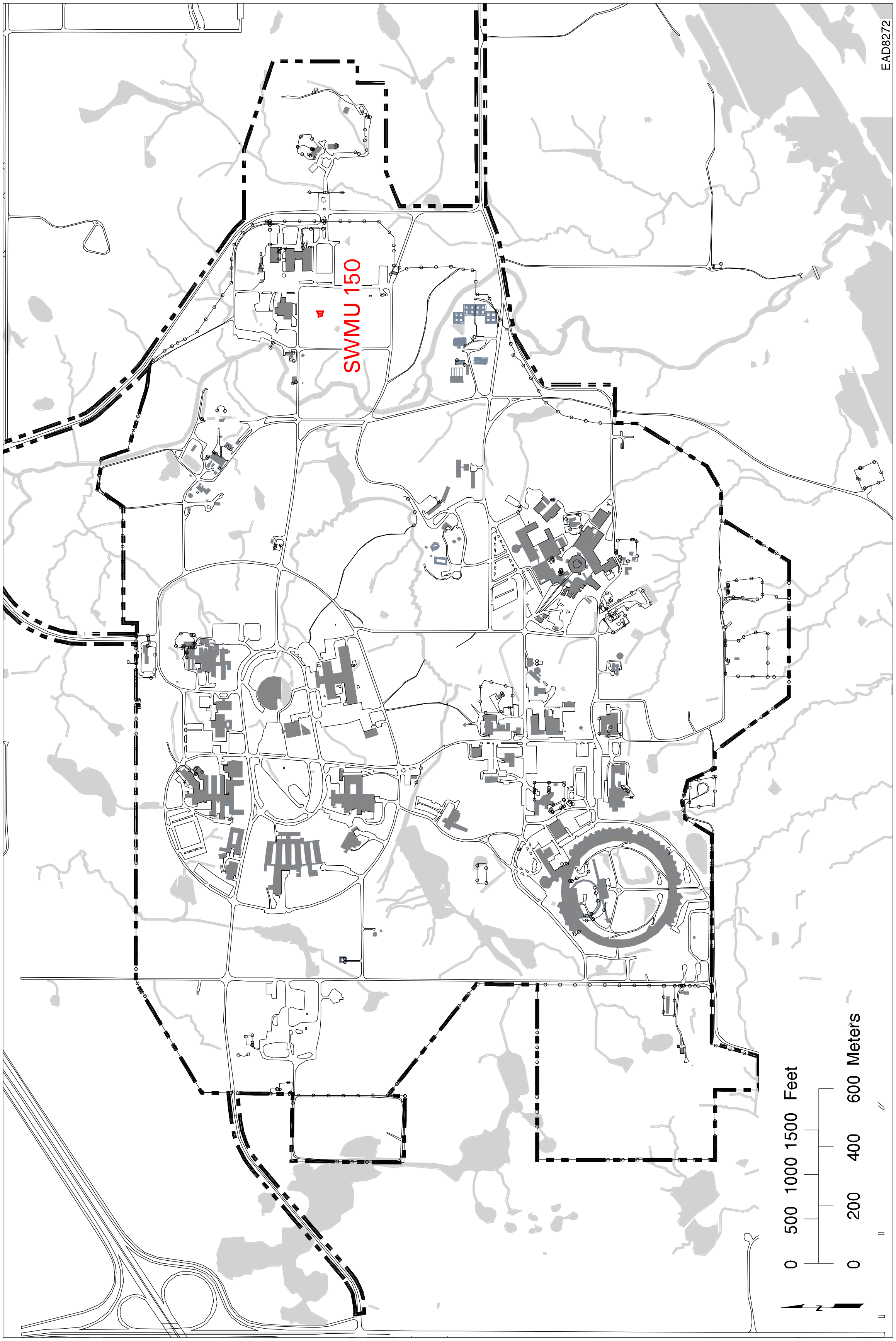


FIGURE 1.2 Location of Building 34 – Liquid Mixed Waste Treatment Plant (SWMU No. 150)

1.3 PROJECT OBJECTIVES

The sampling and analysis program discussed in this report was conducted to supplement earlier investigations to define the nature and extent of contamination, if any, to a degree sufficient to support an NFA request for SWMU No. 150.

This investigation was guided by two principal objectives. The first was to determine the presence and extent of soil contamination through sampling and analysis. Existing soil data from this SWMU indicated that selected contaminants may have been present in soils at levels exceeding soil remediation objectives (SROs). To determine whether this was the case, ANL conducted the final investigation discussed in this report. ANL collected soil samples for analysis and interpreted these additional data by using averaging techniques allowed under the Tiered Approach to Corrective Action Objectives (TACO; 35 IAC 742). Averaged results then were compared with applicable SROs.

The second objective of this investigation was to screen underlying groundwater for contamination and to determine groundwater flow direction. The analytical results of groundwater samples were compared with applicable GROs.

2 ENVIRONMENTAL SETTING

2.1 PHYSIOGRAPHY

The ANL-E site is situated within the Wheaton Morainal Country of the Great Lakes Section of the Central Lowland Physiographic Province (Figure 2.1). The Wheaton Morainal Country is typical of older Wisconsinan glacial drift deposits, with gently sloping topography and a shallow surface relief. This relief is modified, however, in the vicinity of streams and tributaries (such as the Des Plaines River and Sawmill Creek), where the relief is greater, and sharp dissection of moraines is evident. The principal drainage course across the ANL-E facility is Sawmill Creek, which flows along the western edge of the East Area and enters the Des Plaines River approximately 1.3 mi southeast of the center of ANL-E. The Des Plaines River flows southwestward until it joins the Kankakee River about 30 mi southwest of ANL-E to form the Illinois River.

2.2 REGIONAL GEOLOGY

This section discusses the regional geology in the vicinity of ANL-E. Figure 2.2 shows the general stratigraphic sequence at ANL-E, including surficial soils.

2.2.1 Surficial Geology and Soils

On the basis of the *Soil Survey of DuPage and Part of Cook Counties*, *Illinois* (U.S. Department of Agriculture 1979), the following three distinct surficial soils have been mapped within the 317/319/East-Northeast (ENE) Area at ANL-E:

- Blount silt loam,
- Morley silt loam with 2–5% slopes, and
- Morley silt loam with 5–10% slopes.

Blount series soils are found in relatively small areas across the ANL-E site. These soils consist of somewhat poorly drained soil on low ridges and on the slopes of upland drainage ways. Areas composed of this soil are irregular in shape and typically 2 to 30 acres in size. Available water capacity is moderate, permeability is low, and the organic content of the soil is moderately low.

Morley series soils are found over the majority of the ANL-E site. These soils occur on gentle to moderate slopes and are well drained. They are present on sloping to eroded knolls and

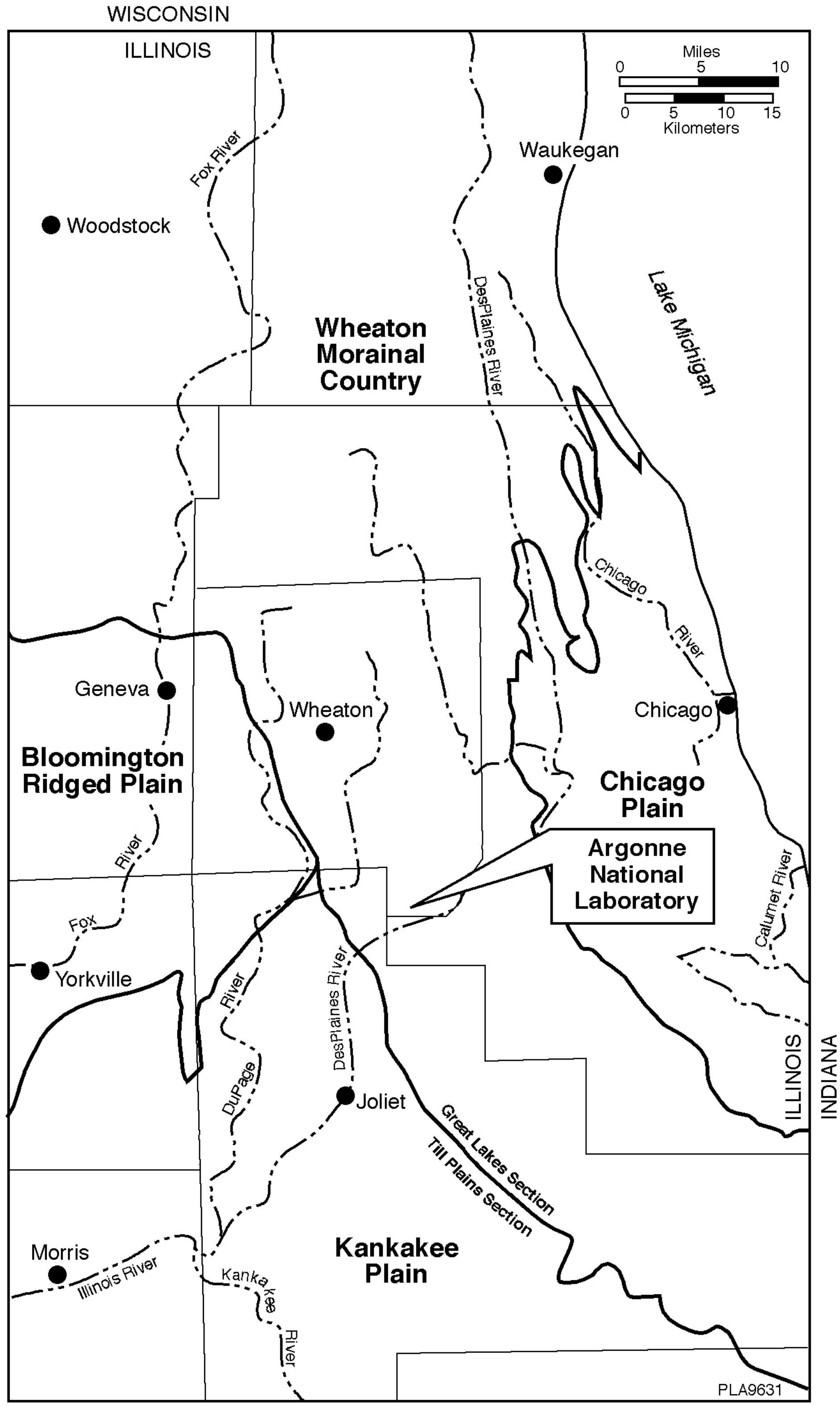
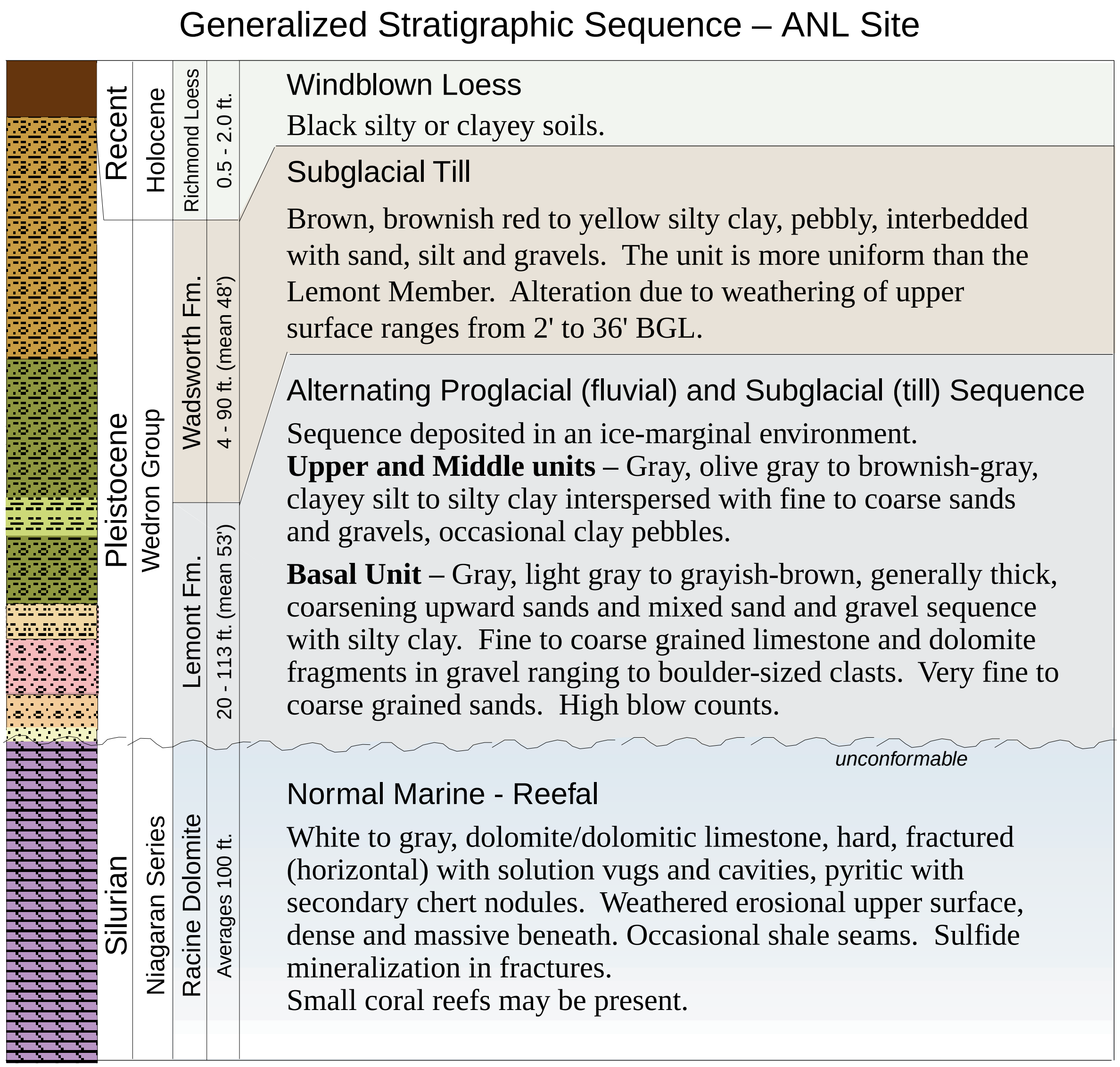


FIGURE 2.1 Physiographic Divisions in the Chicago Area (Source: Willman 1971)



Created by Applied Geosciences and Environmental Management Section, Environmental Research Division, Argonne National Laboratory, 1997.

FIGURE 2.2 Generalized Stratigraphic Sequence for the Shallow Subsurface at Argonne-East

moraines. Areas composed of this soil are irregular in shape and typically 5 to 150 acres in size. Available water capacity is moderate, permeability is low because of the presence of clay, and the organic content of the soil is moderately low to low.

2.2.2 Quaternary Geology

During the most recent glaciation episodes (Late Wisconsinan), which took place between 11,000 and 20,000 years ago, the Lake Michigan lobe of the Laurentide ice sheet extended into Illinois and deposited more than 30 end moraines on the land surface in northeastern and central Illinois during eight major glacial advances (phases) (Hansel and Johnson 1993). ANL-E is situated in the Valparaiso moraine system that locally trends in a northwest-southeast direction (Figure 2.3). Geologic sections compiled from soil borings at and near ANL-E (Killey and Trask 1989; Olimpio 1984) and nearby geologic exposures (Hansel and Johnson 1987) indicate that Quaternary sediments of the Wedron Formation lie directly on dolomite bedrock of Silurian age. The Wedron Formation is composed of sediments from two glacial depositional phases. The Lemont Drift, which lies directly on the bedrock surface, is associated with the Woodstock Phase (16,200 years before present [ypb]). These sediments were subsequently overlain during the Crown Point Phase (≈15,500 ybp) by glacial till deposits of the Wadsworth Member (Hansel and Johnson 1993). Younger sediments such as loess and glacial river bottom gravel were deposited locally.

2.2.2.1 Holocene Deposits

Holocene sediments were deposited in the period following the last (most recent) glacial retreat. They include loess, alluvium (along streams), and organic peat (in swamps and ponds). The loess is more common in undeveloped areas, and it is generally patchy in distribution and less than 5 ft thick (Killey and Trask 1989). Because most natural drainages at ANL-E are erosional, alluvial deposits are not well developed. They can be found near the lower reach of Sawmill Creek (Figure 2.4) and along the Des Plaines River. Peats were deposited in swamps such as those in the western part of the ANL-E site near the 800 Area Landfill and in the Waterfall Glen Forest Preserve north of the Laboratory.

2.2.2.2 Pleistocene Deposits

Glacial River Bottom Deposit. The Des Plaines River was a drainage channel for glacial Lake Chicago near the end of the last glaciation (late Wisconsinan). A veneer of river residual gravel was left behind near the river bank of the Des Plaines Valley (Bretz 1932) after the channel was abandoned (Figure 2.4).

Wadsworth Member. The Wadsworth Member is a poorly sorted glacial till characterized by brown to gray silty clay intermixed with minor amounts of gravels composed primarily of dolomite and shale. The till was deposited under subglacial and supraglacial environments. A few lenses and layers of silt, sand, and gravel are present among the till. Each lens ranges from a few inches to a few feet in thickness. Sand layers with a lateral extent of more than a few thousand feet have been reported at the Palos Forest Preserve and at the Advanced Photon Source (APS) site at ANL-E (Olimpio 1984; Killey and Trask 1994). The total thickness of the Wadsworth till varies in the Valparaiso morainic system, ranging from 20 to 33 ft at the 300 Area, to 81 to 95 ft at the APS site (Killey and Trask 1994) and at the 800 Area Landfill, to about 20 ft at the Palos Forest Preserve (Olimpio 1982), and to 3 ft at Lemont (Hansel and Johnson 1987). At the 300 Area, the elevation of the boundary between the Wadsworth till and its underlying Lemont Drift ranges from 655 to 670 ft above mean sea level (amsl). The

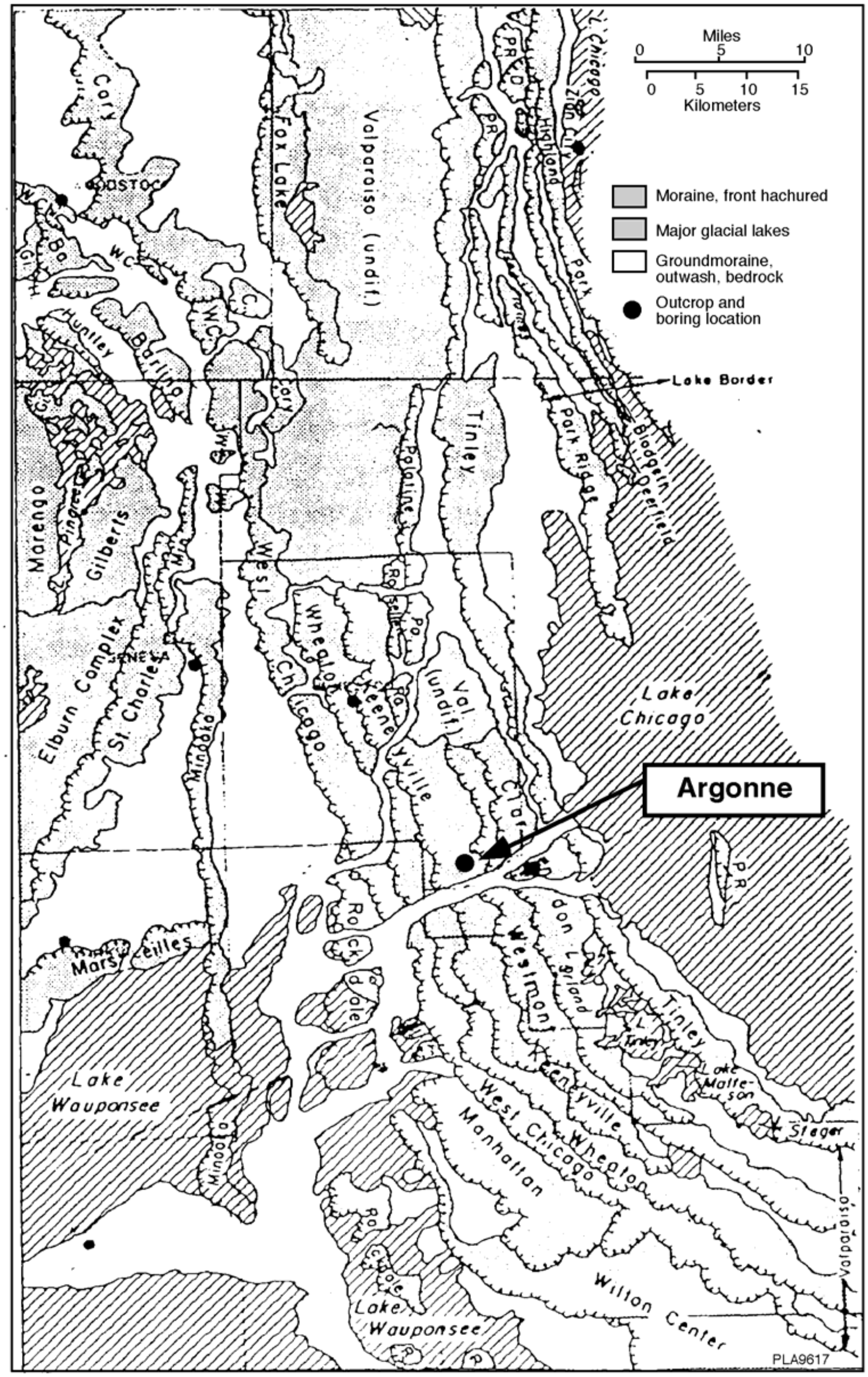


FIGURE 2.3 Distribution of Recessional Moraines near ANL-E (Source: Willman 1973)

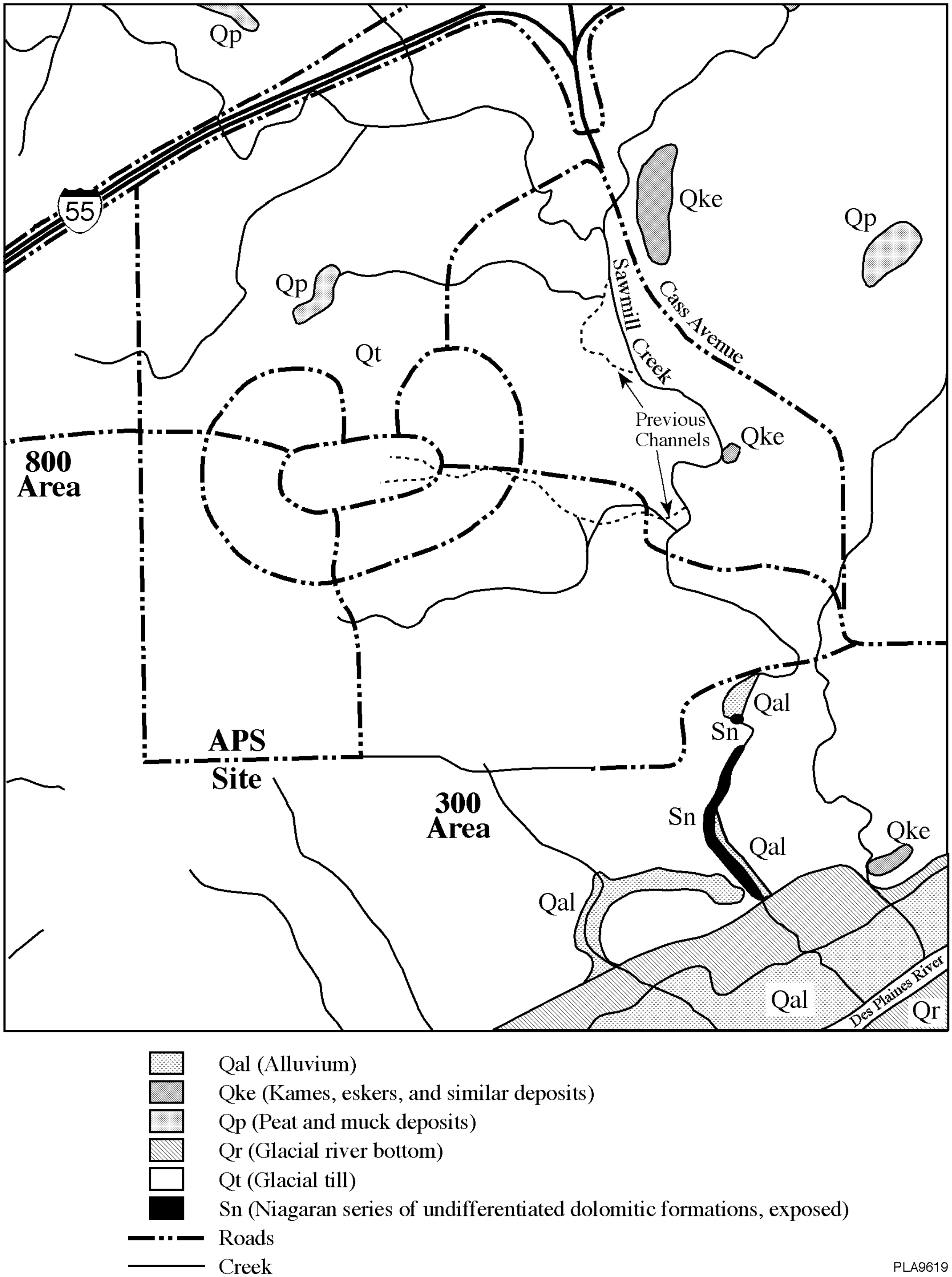


FIGURE 2.4 Quaternary Deposits at ANL-E (Source: Bretz 1932)

Wadsworth till is calcareous. On the basis of an analysis of the grain-size distribution of 47 till samples taken around the APS site, the fine-grained matrix of the till averages 16% sand, 45% silt, and 39% clay. The major clay mineral is illite, which accounts for more than 70% of the total clay particles. Other clay minerals include kaolinite and chlorite (Killey and Trask 1989).

The upper part of the Wadsworth till has been weathered. Iron stains found along fractures in till and weathered brownish till were noted in well logs. The weathered zone varies from 8 to 25 ft (Killey and Trask 1989) below the ground surface (bgs).

Lemont Drift. The Lemont Drift contains a sequence of alternating sorted sediments and tills deposited in a near ice-margin environment (Hansel and Johnson 1987). Near its type location (Lemont Outcrop), the Lemont Drift below the Wadsworth till is represented in descending order by (1) a stratified proglacial fluvial deposit (laminated silt and fine sand, with local pebble lag deposits), (2) a massive silty till, (3) layered diamicton, (4) diamicton interbedded with silt and sand, and (5) a proglacial fluvial layer of sand and gravel. At the 300 Area, the Lemont Drift can be divided into three units: two stratified proglacial fluvial deposits and a silty till in between. The bottom stratified proglacial unit overlies dolomite bedrock and may be correlated to the (3), (4), and (5) units at the type location. The unit contains a combination of layers of coarse-grained sediments ranging from silt, silty sand, and sand, to sand and gravel with a total thickness ranging from 5 to more than 30 ft. The sediment texture can change dramatically over a short distance. This bottom stratified unit can also be found in the borings of the Palos Forest Preserve (Olimpio 1982) and in some of the borings drilled at the APS site, but not at the 800 Area Landfill. The unit is interpreted as containing glacio-fluvial sediments that were deposited in a proglacial environment.

The middle unit of Lemont Drift at the 300 Area is primarily composed of clayey silt with some carbonate pebbles. It is a till correlated to the massive till unit at the Lemont Outcrop type location. Its thickness ranges from 8 to 20 ft. Compared with the Wadsworth till, the till of the Lemont Drift has more silt, and shale pebbles are rare (Hansel and Johnson 1987). Also, the clay-size particles from the Lemont Drift contain more dolomite than calcite (Killey and Trask 1994).

The upper stratified unit of the Lemont Drift consists of laminated silt and fine sand at the Lemont Outcrop type location (Hansel and Johnson 1987). The unit has been interpreted as being of proglacial origin (Hansel and Johnson 1987). At the 300 Area, a sand and gravel layer commonly underlies the silt and fine sand layers. The unit appears to be present throughout the 300 Area, although the texture of the sediment may change with distance and range in thickness from a few feet to 20 ft. At the APS site and the 800 Area Landfill, the stratified unit may be absent.

2.2.3 Bedrock Stratigraphy

The uppermost bedrock unit across the ANL-E facility is the Silurian-aged Racine Formation. The Racine Formation is the youngest formation of the Silurian Niagaran Series and has a maximum thickness of approximately 300 ft in northeastern Illinois (Willman 1971). Underlying the Racine Formation are the Niagaran Series dolomites of the Waukesha and Joliet formations. Combined, these two formations are less than 100 ft thick. The Edgewood and Kankakee Dolomites of the Alexandrian Series complete the Silurian system and make up the next 20 to 150 ft of bedrock underlying the facility.

The Silurian System overlies about 4,000 ft of Ordovician and Cambrian sedimentary rock with alternating carbonate, shale, and sandstone formations. The sandstone formations include the Ordovician St. Peter Sandstone and the Cambrian Mt. Simon Sandstone, which have historically been major sources of potable groundwater in northeastern Illinois.

2.3 REGIONAL HYDROGEOLOGY

In northeastern Illinois, groundwater is obtained from three major sources: glacial drift aquifers, shallow bedrock (dolomite) aquifers, and deep bedrock (sandstone) aquifers (Hughes et al. 1971). The Silurian dolomite is the primary water supply aquifer beneath the ANL-E site. The dolomite yields water primarily from fractures, bedding planes, and solution cavities. In northeastern Illinois, this aquifer is generally recharged from overlying drift.

ANL-E formerly obtained its water from four production wells installed in the shallow dolomite bedrock aquifer, until the Laboratory switched to Lake Michigan water in 1997. A fifth production well was installed in a deeper sandstone aquifer; however, this well is no longer in use. The wells were installed between 1948 and 1959. The ANL-E water-supply wells pumped at a rate of 300 to 500 gallons per minute (gpm). Pump tests conducted in the 1950s indicate transmissivity values ranging from 7,000 to 9,000 gal/d/ft (Geraghty and Miller, Inc. 1993).

Hydraulic conductivities have been estimated in the glacial till from tests conducted approximately 3,600 ft northwest of the 317/319/ENE Area. The results of these tests indicate hydraulic conductivities ranging from 3.2×10^{-7} to 4.2×10^{-6} cm/s (Killey and Trask 1989).

2.4 SURFACE WATER

The ANL-E site is drained principally by Sawmill Creek, which empties into the Des Plaines River. Sawmill Creek flows about 900 ft west of SWMU No. 150, along the west edge of the East Area. Surface water drainage from the East Area flows or is conveyed through storm sewers to Sawmill Creek. Treated sanitary and laboratory wastewater are combined and discharged into Sawmill Creek in accordance with the requirements of the ANL-E National Pollutant Discharge Elimination System (NPDES) permit. The combined ANL-E effluent consists of approximately 40% treated laboratory wastewater and 60% treated sanitary wastewater. Surface water flow in Sawmill Creek was estimated to be approximately 5.9 million gal/d in 1995.

3 GENERAL DESCRIPTION OF FIELD ACTIVITIES

The soil and groundwater investigation Work Plan (ANL 1998) was implemented intermittently over a 15-month period by qualified ANL-E personnel with a variety of experience in environmental characterization activities. The samples collected by the ANL-E team were sent to a qualified analytical laboratory — Paragon Analytics, Inc., of Fort Collins, Colorado — which performed standard chemical and radiological analysis.

The following sections describe the general procedures that were followed to collect, preserve, document, analyze, and dispose of both investigative and quality assurance/quality control (QA/QC) samples. Except for minor deviations discussed in the following sections, the sampling was completed in accordance with the approved soil and groundwater investigation Work Plan (ANL 1998). This discussion summarizes the sampling procedures that were followed. A more complete discussion, including detailed standard operating procedures, is provided in Section 4 and corresponding appendixes of the approved Work Plan. The more detailed procedures are not reproduced in this report.

3.1 CHRONOLOGICAL SUMMARY OF FIELD ACTIVITIES

Field work was initiated in November 1999 and completed in February 2001. A total of 22 soil borings were drilled, 10 new monitoring wells were installed, and 95 soil samples and 26 groundwater samples were collected. In general, soil boring and monitoring well installation activities occurred first, followed by monitoring well development, purging, and sampling. Drilling began in November 1999 and was completed in July 2000. Groundwater sampling began in February 2000 and was completed in February 2001. Activity field logs summarizing each day's activities are contained in Appendix B. Figure 3.1 shows the locations of all soil borings and monitoring wells installed in the vicinity of SWMU No. 150.

3.2 SUBSURFACE SOIL SAMPLING

Subsurface soil samples were collected on a continuous basis with the aid of a Central Mine Equipment (CME) 75 all-terrain vehicle (ATV) drilling rig. Undisturbed soil cores were collected in accordance with the American Society for Testing and Materials (ASTM) Standard D1586-84 (ASTM 1997). A hollow-stem auger was used to advance the borehole at 2-ft intervals. At the top of the sampling interval, borehole advancement stopped, and a stainless-steel split-spoon was attached to the drill rod. The split-spoon was then driven into the undisturbed soil immediately below the bottom of the auger string. Figures 3.2 and 3.3 show soil boring activities and split-spoon sampling.

Soil samples for volatile organic compound (VOC) analysis were considered grab samples and were collected in a manner that would help minimize the volatilization of VOCs from the soil during sample collection. The ANL-E field sampler used an EnCore™ 5-mg

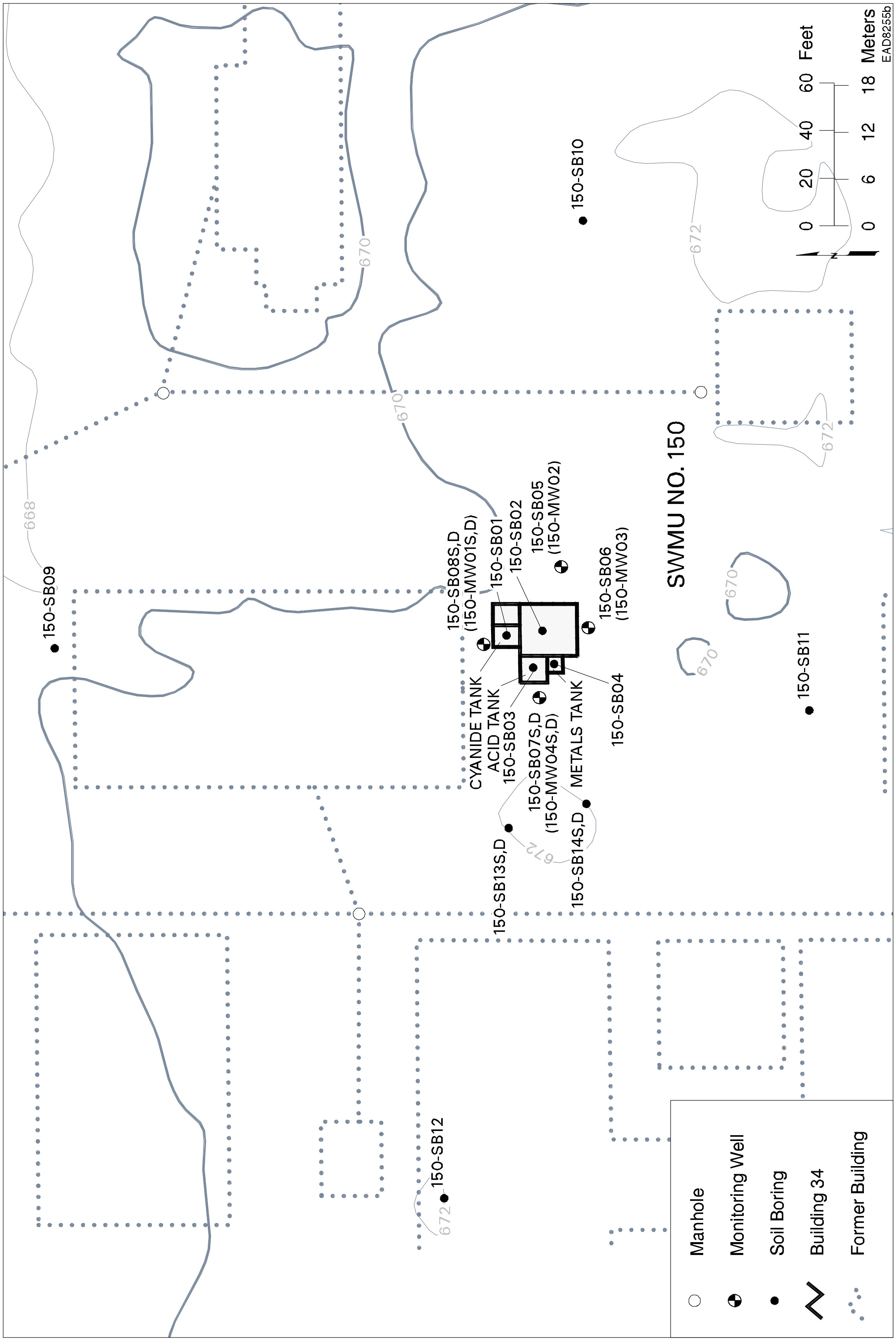


FIGURE 3.1 Locations of Soil Borings and Monitoring Wells Installed in the Vicinity of SWMU No. 150

FIGURE 3.2 Photograph Showing Soil Boring Activities

FIGURE 3.3 Photograph Showing Split-Spoon Sampling Activities

syringe sampler to collect soil for VOC analysis. At each 2-ft interval, the syringe sampler was attached to a T-handle, then pushed into the center of a section of undisturbed soil core. Sufficient volume was collected when a rubber gasket of the syringe stem appeared in a measurement window on the T-handle. A locking cap then was affixed to the full syringe sample, and the sample was placed in a dedicated sealed bag. Three 5-mg EnCore™ syringe samples were collected for each VOC sample.

Soil samples for SVOC, pesticides/PCB, metals, and radionuclide analysis were collected by placing an aliquot of soil from each 2-ft interval into a stainless steel bowl. At the completion of each borehole, the soil was thoroughly mixed using a stainless steel spoon, then placed into the appropriate sample containers. These homogenized, or composite samples, were considered representative of the entire soil column. The stainless steel bowl and spoon were decontaminated between each soil boring.

3.3 MONITORING WELL INSTALLATION

Groundwater monitoring wells were constructed in soil borings created by the subsurface soil sampling process, as well as in blind-drilled borings immediately adjacent to borings that had been sampled. For each well cluster, continuous split-spoon sampling was conducted during drilling of the first boring (typically the deepest boring of the cluster). The geological information from this boring was reviewed by the field geologist to determine the sampling depths for the subsequent shallow and intermediate borings and the screened intervals for monitoring wells. Borings for these wells were blind-drilled to the desired depth. In some cases, split-spoon samples were collected at the bottom of the blind boring to confirm that the desired interval had been reached or to obtain subsurface soil samples from depth horizons not sampled during the continuously sampled borings because of low sample recovery or obstacles.

The monitoring wells were constructed of 2-in.-diameter, flush-threaded, polyvinyl chloride (PVC) riser pipe and 0.010-in. stainless-steel slotted screen. Screens measuring 5 ft in length were used for the shallow water table wells, and either 5-ft or 10-ft screens were used for the deeper wells.

Upon selection of the screened interval, the well casing was placed in the borehole. A silica sand pack was placed in the annular space between the screen and the borehole, extending approximately 2 ft above the screen. Measuring tape was used to measure the thickness of the sand as it was added, to ensure that the appropriate amount of sand was used. In the event that the water table was above the silica quartz sand pack, the borehole’s annular space was filled with a pure bentonite grout. The grout was placed by using a side-discharge tremie-pipe from the top of the silica quartz sand pack to about 2 ft bgs. Because the grout consisted of pure bentonite and did not contain any cement, a bentonite pellet seal was not required above the silica quartz sand pack. The slurry was pumped at a low rate through the tremie-pipe until all existing borehole fluids were displaced. If the water table was noted to be below the top of the silica quartz sand pack, the borehole’s annular space was filled with bentonite pellets, which were hydrated during placement. The upper part of the borehole was then filled with concrete. An outer protective casing was placed around the aboveground part of each monitoring well riser and pushed into the wet concrete. Figure 3.4 shows a stainless steel well casing being lowered into the borehole. Figure 3.5 shows the silica quartz sandpack being placed around a well screen. Figure 3.6 shows concrete being placed around a newly installed monitoring well and outer protective casing. Appendix C contains monitoring well completion forms for all the monitoring wells installed during this investigation.

3.4 MONITORING WELL DEVELOPMENT

3.4.1 Standard Procedure

Each well was developed a minimum of 48 h after its construction. A submersible pump was used to remove the appropriate volume of water and sediment from the well and sand pack. If the well was not free of sediment after the appropriate volume of water had been removed, the pumping continued until twice the specified volume of water had been removed.

The following steps were followed in developing the monitoring wells:

1. Static water levels were recorded.

2. The initial pH, temperature, specific conductance, and any other required or pertinent measurement(s) of the water were taken and recorded.

3. For wells in which the boring was made without the use of drilling fluid (water), five times the standing water volume in the well (well screen and casing plus saturated annulus) was removed. If recharge was so slow that five volumes could not be removed in an 8-h period or the water was not sediment free, an alternate development procedure was used. This alternate procedure is discussed fully at the end of this subsection.

4. Except for a few cases, no water was introduced into the wells to assist development. Small amounts of potable water were used to clean poorly yielding wells. This task was accomplished by pumping or pouring in buckets of potable water.

5. For those wells in which the boring was made or enlarged by the use of drilling fluid (water), five times the measured amount of total fluids lost while drilling plus five times the standing water volume were removed.

6. The initial and final color, clarity, and odor of the water were recorded.

7. The final pH, temperature, and specific conductance of the water were recorded.

8. The appropriate data were entered into the log book.

FIGURE 3.4 Photograph Showing Stainless Steel Well Casing Being Lowered into a Well

FIGURE 3.5 Photograph Showing Placement of Silica Quartz Sandpack around a Well Screen

FIGURE 3.6 Photograph Showing Placement of Concrete around a Newly Installed Monitoring Well

3.4.2 Procedure for Slow Recharging Wells

The procedure for development of several of the groundwater monitoring wells was modified because (1) the volume of drilling fluids lost to the formation near the surface of the dolomite bedrock was much higher than anticipated and the recovery rates of the wells screened in this formation were very slow, and (2) recharge rates for wells installed in the glacial till were so low that the wells were repeatedly pumped dry during initial development. The well development procedures outlined in Appendix J of the approved Work Plan (ANL 1998) state that "for those wells where the boring was made or enlarged with the use of drilling fluids (water), remove five times the measured amount of total fluids lost while drilling plus five times the standing water volume." However, during drilling and installation of several bedrock monitoring wells, large quantities of drilling fluid (water) were lost as the drilling bit passed through the uppermost layers of the weathered bedrock surface. In these instances, removal of five times the standing water volume was attempted. However, it was quickly determined that the recharge rate of the wells, which were screened into more competent dolomite several feet lower than the interval where the water loss occurred, was so low that removing the stated quantity of water was not feasible. As allowed for in Appendix J of the Work Plan, an alternate procedure for developing these wells was used. This alternate procedure is summarized in the following steps.

1. A pump or bailer was used to evacuate a volume of water (minimum of one volume and maximum of five volumes) that was recorded as being lost during drilling.

2. Upon evacuation of the volumes, wells were developed as specified in the approved Work Plan.

3. Wells were then purged and sampled no sooner than 12 h after development.

If the volumes of water described in (1) above could not be obtained within an 8-h pumping period because of low flow, slow recharge, or an excessively large water volume that was impractical to remove by pumps designed for small-diameter (2-in.) wells, the following procedures were implemented:

1. The volume of water evacuated during the initial 8-h well development attempt was recorded.

2. Pumping or bailing was continued, and measurements of pH, temperature, and specific conductance were frequently recorded.

3. The well was considered adequately developed when the above parameters had stabilized following the initial 8-h development attempt. Stabilization

under these alternate procedures was defined as 10 consecutive readings for each parameter within the following tolerances:

- pH values within a range of 0.5 units,
- Temperature values within a range of 1°C, and
- Specific conductance within a range of 100 μmhos/cm.

3.5 MONITORING WELL PURGING AND SAMPLING

All groundwater samples were collected by using the MicroPurge™ low-flow groundwater sampling system. This innovative sampling method allows the pumping rate to be regulated so that the groundwater intake velocity more closely matches the natural groundwater flow velocity. The MicroPurge™ system was used in an effort to minimize interference from suspended colloidal clay particles frequently encountered in glacial till wells installed across the ANL-E site. The MicroPurge™ technique was found to reduce the disturbance of silt in the well bottom during sampling.

The MicroPurge™ low-flow system uses a pneumatic bladder pump powered by a compressed air source. Figure 3.7 is a schematic diagram showing a MicroPurge™ pump in a well. Groundwater is withdrawn from the well in two alternating cycles. During the discharge cycle, air is forced into the space between the pump body, and the bladder pump squeezes the water inside the bladder into the exit/entrance holes of the fill rod. As the air pressure increases, groundwater is forced up the discharge line and to the surface. The bottom check-valve ball is forced down by the air pressure in the pump, thus sealing the inlet so that no water can enter the bladder chamber. During the refill cycle, with no air pressure holding it down, the bottom check-valve ball is pushed up by the inflowing water pressure, allowing water to reenter the bladder chamber. The bladder expands as it fills with water. The top check-valve ball seals because of the force of the water pressure in the discharge tubing.

The bladder pump is suspended in the water column by using polyethylene tubing connected to fittings on a well cap. Fittings include a compression fitting for the water discharge line, a short brass quick-connect nipple for the compressed air supply line, a stainless-steel quick-connect nipple for the water level meter, and a stainless-steel quick-connect nipple for the freeze line. Bladder pump operation is controlled by a cycle controller. The controller acts as a regulator of the compressed air source to the pump. The controller alternately pressurizes, then vents, the air supply line to the pump, thus allowing the pump to discharge, then fill with water. The pumping rate is optimized by means of a discharge and refill timer. Figure 3.8 is a photograph showing collection of a field turbidity measurement. Figure 3.9 is a photograph showing collection of groundwater samples by means of the MicroPurge™ low-flow sampling pump.

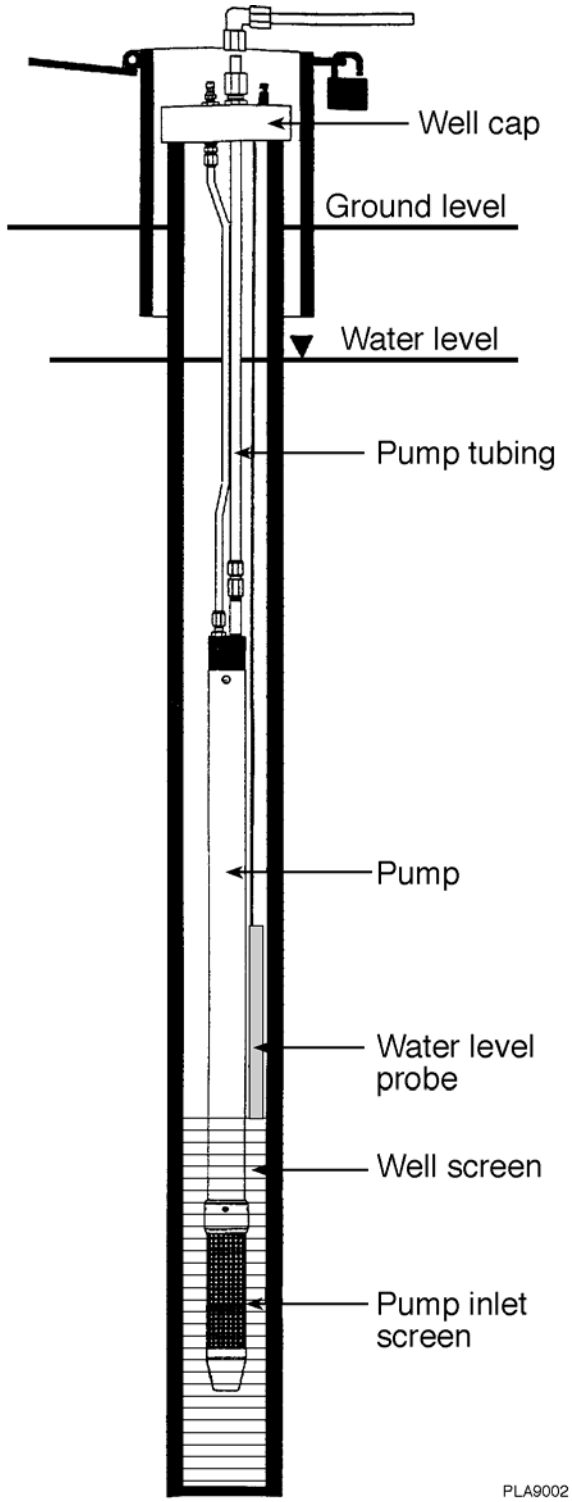


FIGURE 3.7 Schematic Diagram Showing a MicroPurge™ Pump in a Well

FIGURE 3.8 Photograph Showing Collection of Field Turbidity Measurements

FIGURE 3.9 Photograph Showing Collection of Groundwater Samples Using the MicroPurge™ Low-Flow Sampling Pump

A Well Wizard® model 6400 electronic water-level meter was used to monitor hydraulic head during sampling activities. A stainless-steel water-level probe was connected to the water-level meter by polyethylene tubing. Prior to pumping, an air bubble was pushed to the bottom of the probe, then the bubble was allowed to stabilize at the groundwater surface. The depth of this bubble, measured by the difference between the bottom of the water-level probe and the air-bubble stabilization value, represented the hydraulic head and was monitored for changes throughout sampling.

3.6 FIELD SCREENING

3.6.1 Soil Sampling

At each boring location, soil was field screened for VOCs on a continual basis. Field screening results were used to determine the presence of VOCs and, if present, the vertical and lateral extent of VOC contamination in the soil column across the borings at the SWMU. Field screening was conducted by measuring organic vapor concentrations in the headspace above a sample of the soil. Headspace organic vapor measurements were performed by means of a Microtip Photovac® MP-1000 photoionizing detector. Soil samples were placed in a clean, wide-mouth jar, covered with aluminum foil, and heated in a portable oven to approximately 100^{o}F for about 10 min. Use of a standard temperature for headspace readings ensured uniform measurement conditions independent of outside air temperature fluctuations. Field screening results were recorded on the field boring log in the “OVA or Hnu Readings” column.

In most instances, after soil samples were heated, excessive condensation was noted inside the field screening jars. Field screening for VOCs in these jars using the photoionization detector resulted in consistently elevated measurements, in the range of 70 to 90 ppm. Results of VOC analysis from these same sampling intervals showed VOC concentrations below analytical method detection limits (MDLs). The MDL of the Photovac® MP-1000 photoionization detector is 0.1 ppm, well above the detection limits of the VOCs that were analyzed for in the samples. Additionally, EPA studies have indicated that, although this method of headspace field screening provides more consistent results, readings may remain relatively inconsistent because volatilization of contaminants is affected by, among other things, the moisture content in the soil sample (EPA 1997). ANL therefore concluded that the elevated VOC readings observed in most of the soil samples collected are the result of high humidity levels in the jar headspace caused by moisture being driven off of the soil during heating.

3.6.2 Groundwater Testing

3.6.2.1 Temperature Readings

Temperature information is required to normalize data obtained from other analyses, such as those for determining pH and specific conductance. Temperature readings were taken on unpreserved samples immediately after they were collected. The readings were obtained by partially immersing a temperature probe with a normal range of 0–50°C into a sample. The readings for each sample were documented immediately on the sample collection form.

3.6.2.2 pH Readings

The pH reading is a measure of the effective hydrogen-ion concentration. It is defined as the negative logarithm of hydrogen ion activity in a sample and is very useful for assessing the acidic or basic nature of a body of water and for elucidating complex chemical reactions that occur in water. The pH of water was determined by using the following procedures:

1. The electrode was rinsed with deionized water.

2. The sample was transferred into a sample jar.

3. The electrode was inserted into the sample solution and allowed to equilibrate for a few minutes.

4. The pH values on the pH meter were read to the nearest 0.1 and the value was recorded.

5. The electrode was rinsed with deionized water between each measurement.

3.6.2.3 Specific Conductance Readings

The ability of a solution to carry an electric current under specific conditions is reflected by its conductance value. This value also indicates the concentration of dissolved solids in natural water. Because the specific conductance of a sample can change over time, this value was determined in the field. This field measurement can also aid in assessing whether or not a sample is representative of the site. The specific conductance of water was determined by inserting a probe into an aliquot of water. Readings were recorded in μmhos/cm on the sample collection form.

3.6.2.4 Turbidity Readings

The turbidity reading measures the degree to which light traveling through a water column is scattered by the suspended organic and inorganic particles. The scattering of light increases with a greater suspended load. Turbidity is commonly measured in nephelometric turbidity units (NTUs). Monitoring of turbidity during this investigation was particularly important because metals were determined to be contaminants of concern in the groundwater. ANL believes that elevated metals concentrations are often the result of suspended soil particles in the groundwater. The sampling method used during this study, the MicroPurge™ method, relies on turbidity measurements to control the rate of pumping. Low turbidity measurements would indicate relatively small amounts of suspended solids in a groundwater sample. A LaMotte Model 2020 Turbidity Meter was used to collect measurements. A small aliquot of groundwater was placed in a vial, then inserted into the meter. Readings were recorded to a tenth of an NTU. Initially, ANL used a target turbidity value of 100 NTUs during purging, which was based on a recommendation by the manufacturer. However, after the first two rounds of sampling, the presence of elevated levels of metals caused ANL to reduce the target NTU level to 10 NTUs in an effort to reduce the amount of suspended solids in the samples. Therefore, later groundwater samples were collected for total metals analysis when turbidity readings were less than or equal to 10 NTUs.

3.7 SAMPLE PRESERVATION

All samples collected for analysis were preserved and shipped in accordance with EPA SW-846 procedures (EPA 1986). The analytical laboratory provided all sample bottles and certified the cleanliness of the containers. The analytical laboratory also provided prepreserved sample bottles for the field sampling team.

3.8 DOCUMENTATION

3.8.1 Sample Chain of Custody

Sample containers were affixed with a sample label identifying the sample number, date, and type of analysis requested. The ANL-E sampling team was responsible for the care and custody of the sample until the sample was properly dispatched. A chain-of-custody form was completed and placed with the samples before packaging and storage. Information documenting the history of the sample — from collection time to shipment time, through transport and analysis — was recorded on this form. Copies of completed chain-of-custody forms were retained by the project engineer. Each chain-of-custody form was sealed in a watertight package and placed in a sealed shipping container before being released to the carrier. Copies of the chain-of-custody forms, completed by the analytical laboratory to document receipt of the samples, were transmitted to ANL-E with the analytical data package.

All chain-of-custody records were kept in the project file to document that the samples were properly managed to prevent tampering and that the samples were received undisturbed by the laboratory.

3.8.2 Field Data Documentation

Sample collection activities were documented in bound field logbooks with numbered pages. Entries were as detailed and descriptive as possible so that a particular situation could be recalled without having to rely on the memories of the field sampling team. In addition, these activities were documented with photographs, which are included in this report.

3.9 DECONTAMINATION OF FIELD SAMPLING EQUIPMENT

The procedure involved in decontaminating sampling devices (i.e., split-spoons and scoops) included the following steps:

1. Sampling equipment was scrubbed with an Alconox solution (a nonphosphate detergent) and potable water. Soft-bristle brushes were used to remove soil or other materials from sampling devices.

2. Equipment was rinsed with potable water.

3. Equipment was rinsed several times with distilled water and allowed to air dry.

All decontamination activities occurred in designated decontamination zones in the work area. Rinsate was containerized in 10-gallon plastic buckets, then discharged to ANL-E’s laboratory sewer system.

3.10 SAMPLE ANALYSIS

3.10.1 Analytical Methods

Chemical analyses were completed by Paragon Analytics, Inc., which followed the most recent version of EPA SW-846 procedures (EPA 1986). Radiological analysis was also performed by Paragon in accordance with DOE Environmental Monitoring Laboratory procedures. Appendix D provides the analytical data sheets. Certification statements by the QA manager are provided in Appendix A. The QA/QC methods used are described in Section 3.11.

3.10.2 Presentation of Data

After analytical data were validated by the analytical laboratory, they were summarized in accordance with accepted QA practices to show the results of analytical detections that were above reporting limits. Field investigation data and laboratory analytical data are presented in tabular form, where applicable, in the results sections of Chapter 5. Data were sorted so that they could be presented in a manner appropriate to the discussion. When no constituents were detected, or very limited concentrations were detected, data summary tables were not prepared and are not presented; these results are discussed only in the text. Data summary tables present the results of detected constituents (i.e., hits) only.

Standard reporting units were used in the data summary tables. Inorganic (metals) data are shown in mg/kg for soil and in mg/L for aqueous matrices. Organic compounds are shown in µg/kg for soil and µg/L for aqueous samples. Radiochemistry data are reported in pCi/g for soil and pCi/L for aqueous matrices.

3.10.3 Data Qualifiers

Following sample analysis, data qualifiers were assigned to analytical data, as necessary, by the analytical chemist either during or after sample analysis or after internal data validation in accordance with QA guidelines. Data qualifiers commonly found in the raw data packages and used on data summary tables include the following:

- “U” indicates that a compound was analyzed for but not detected. The associated numerical value is the estimated sample quantitation limit (QL), which is included and corrected for dilution and percent moisture.

- “J” indicates an estimated value for organics analysis. This qualifier is used when a concentration for a tentatively identified compound (TIC) is being estimated or when mass spectral data indicate the presence of a compound that meets the identification criteria but is present at a concentration below the detection limit.

- “B” indicates that the compound was found in the associated method blank sample as well as the investigative sample under analysis. This qualifier indicates possible/probable blank contamination.

- “D” indicates that the compound was identified in an analysis at a secondary dilution factor.

3.11 QUALITY ASSURANCE/QUALITY CONTROL

Chemical and radiological data were used to fulfill the project objectives, as discussed in Chapter 1. The quality of the analytical data is defined as the degree of certainty of a data set with respect to precision, accuracy, reproducibility, comparability, and completeness. Data quality objectives (DQOs) are qualitative and quantitative statements that specify the quality of the data required to support management decisions. They are determined on the basis of the end uses of the data to be collected. As described in the approved Work Plan (ANL 1998), five data quality levels, which address various data uses and the QA/QC effort and methods required to achieve the desired level of quality, apply to this project. Level IV (confirmational) applies to laboratory chemical and radiological analyses. This level provides the highest data quality that can be used for risk assessment and evaluation of remedial alternatives.

Full analytical validation and data validation are often performed on data with a Level IV DQO; however, these procedures were not required for this investigation. To evaluate the quality of the analytical data, full EPA Contract Laboratory Program (CLP)-type data analyses were performed by the analytical laboratories, and representative portions of the data packages were submitted for external data validation in accordance with EPA guidelines.

3.11.1 Field Quality Control

QA/QC samples were collected for laboratory analysis to verify the analytical accuracy and precision of field sampling activities. Field QA/QC samples included field duplicates, field blanks, matrix spike/matrix spike duplicates (MS/MSDs), and trip blanks.

Field duplicate samples were used to measure the precision of the sampling techniques. These samples were applicable to all laboratory analyses. One field duplicate sample was taken for each set of 10 investigative samples collected per matrix (e.g., soil, water).

Field blank samples were employed to evaluate the decontamination technique used for sampling equipment not dedicated to a given sampling location. These samples were prepared by filling sample bottles with organic-free deionized water that had been routed through a decontaminated sampling device, including the filtering apparatus. Field blanks were applicable to all laboratory analyses except geotechnical analyses and alkalinity. One field blank was taken for each set of 10 investigative samples collected when nondedicated equipment was used.

Trip blank samples were used to detect potential sample contamination during handling or storage. Trip blanks were monitored for VOC contamination during sample transport and storage. The samples were prepared in the laboratory by filling vials with organic-free deionized water, sealing the vials (with no air bubbles allowed), and transporting them to the site. Trip blanks were applicable to VOC analysis. One trip blank was taken for each cooler containing VOC water samples.

MS/MSD samples were used to assess the accuracy of laboratory analyses. MS/MSD samples were applicable to VOC, base-neutral-acid (BNA), pesticide/polychlorinated biphenyl (PCB), and inorganic analyses. Only MS samples were applicable for metals, tritium, gross alpha, gross beta, and gamma spectrometry analyses. Both MS and MS/MSD samples were taken once for each set of 20 investigative samples collected per matrix (e.g., soil, water). MS/MSD samples are collected in the field; however, their use is described under laboratory QC procedures (Subsection 3.11.2).

Additional QA/QC efforts included internal QC checks for field measurements. Calibration and calibration checks were used for the QC of accuracy, and duplicate measurements were taken for the QC of precision.

Preventive maintenance was performed on all field equipment to ensure proper operation and to prevent any contamination of samples caused by fluid leaks from this equipment.

The results of the field QC sample analysis program were evaluated to ensure that field data collection activities (e.g., decontamination, sampling, storage, shipment) did not introduce potential contaminants into the sample matrices, because these contaminants could be misinterpreted or erroneously attributed to historical SWMU activities. This evaluation consisted of reviewing analytical data from field QC samples (i.e., duplicates, field blanks, and trip blanks). Field duplicate samples were evaluated to determine whether results from the investigative sample and the QC duplicate sample were comparable. Field blank and trip blank samples were evaluated to determine whether constituents were present and, if so, to explain their presence. MS/MSD sample results were evaluated as part of internal (laboratory QA review) and external (data validation) activities; the results of this evaluation are discussed in subsequent subsections.

The QC field duplicate sample analyses indicated that, in general, analytical results from investigative and duplicate samples in each sample matrix were comparable. QC field duplicates for aqueous matrix samples (groundwater) were observed to correlate well with investigative sample results.

An evaluation of QC field blank and trip blank samples indicated that, in general, very few constituents were detected in these samples. This finding indicates that associated field data collection activities (e.g., decontamination, sampling, storage, shipment) were performed properly and effectively limited the potential for cross-contamination of samples. When constituents were detected, the compounds noted were composed primarily of common laboratory contaminants [e.g., acetone, methylene chloride, 2-butanone, bis(2-ethylhexyl)phthalate, di-n-octylphthalate]. The presence of these constituents is attributable to standard analytical laboratory equipment and procedures. When constituents other than common laboratory contaminants were detected, they were generally detected at very low and estimated concentrations.

3.11.2 Laboratory Quality Control and Calibration Procedures

For organic compounds and metals, the acceptance criteria were based on the advisory limits of EPA SW-846 (EPA 1986). For radiological analyses, the acceptance criteria were based on laboratory-derived control limits established by statistical treatment of laboratory data. Various laboratory QC samples are discussed in the following paragraphs.

Method blank samples were used to monitor the introduction of artifacts that could result from sample preparation or the analytical method into the analyses. The method blank was carried through the entire analytical procedure (i.e., extraction, concentration, and analysis).

MS samples monitor the effect of the sample matrix on analytical accuracy. MS samples were collected in the field and prepared in the laboratory by adding predetermined quantities of specific analytes to the sample matrix before extraction and digestion. Percent recoveries were calculated for each analyte to assess analytical accuracy. MSD samples were also collected to assess analytical and sampling precision by calculating a relative percent difference between the primary and duplicate spike recoveries. The MSD sample was a duplicate of the selected matrix spike. Results of MS/MSD analysis are included in Appendix D.

In addition to the above laboratory QC analyses, laboratory personnel completed additional procedures including calculation of surrogate spike recoveries, analysis of replicate samples, evaluation of gas chromatography/mass spectrometry tuning criteria and retention-time windows, application of internal standards, and performance checks.

3.11.3 Data Reduction, Validation, and Reporting

Analytical results were calculated from the raw data as prescribed in the various analytical methods. The step-by-step calculations are provided in the referenced analytical method. Laboratory data were stored in files maintained by the laboratory and documented in soil and aqueous data packages submitted to ANL-E. Data included calibration records, raw analytical data, information on processing of data, internal data validation records, QC sample results, data reports, and project-specific requirements.

Internal laboratory data validation was performed in accordance with the analytical laboratory’s QA plan. At a minimum, approximately 5% of the data packages generated were reviewed by the laboratory QA supervisor in accordance with laboratory QA requirements. External data validation was performed by independent ANL-E analytical chemists.

Data were reported both electronically and as hard copy. Each laboratory data report package for each type of analysis contained a case narrative as well as a copy of the chain-of-custody record for that data package. The complete data packages are not included with this report because of the large quantity of information they contain. Copies of the analytical data sheets are included in Appendix D. They will be maintained by ANL-E in the event that a review of the information contained in them is required.

3.11.4 Data Quality Assessment

External data review was performed on selected data packages as part of the investigation activities. The results for 38 soil and 4 groundwater samples were submitted for data validation. Non-radiological data review was performed by ANL-E's Analytical Chemistry Laboratory (ACL) in accordance with guidelines established for the EPA Contract Laboratory Program (CLP). Radiological data were reviewed using the analytical laboratory's (Paragon) radiological standard operating procedures. Overall data quality was reviewed by an analytical chemist from ANL-E, who scanned case narratives and data packages for comments and nonconformances.

As a result of their data quality review, ANL-E analytical chemists judged all data reviewed to be acceptable or to be qualified as estimated but usable on the basis of slight deviations from various QC criteria. No analytical data reviewed were rejected. The analytical laboratory's QA certification form is provided in Appendix A. The results of ANL-E data validation are summarized below.

3.11.4.1 Soil Samples

VOC Data

The data packages for VOC analyses contained data on field samples as well as on associated laboratory blanks, laboratory control spikes, and laboratory control spike duplicates, and calibration data. All samples were analyzed within the specified holding times. All initial and continuing calibration data met the applicable criteria except that 2-chloroethylvinylether was not detected in the continuing calibration standard from November 24, 1999. Method blanks associated with these samples contained methylene chloride and, in one instance, naphthalene was detected at a concentration below the reporting limit. The data were determined to be acceptable.

SVOC/PCB/Pesticide Data

For SVOC samples, all QC criteria were met, and the data were determined to be acceptable. For two soil samples, instead of MS and MSD, laboratory control spike (LCS) and laboratory control spike duplicate (LCSD) samples were analyzed.

With the exception of two PCB samples, all QC criteria were met, and the data were determined to be acceptable. In one data package, continuing calibration #1 tetrachloro-m-xylene (TCMX) was out low on the second column. We reported the results from the column that met calibration criteria; MS and MSD values were not within the acceptance criteria for Aroclor 1016. The recoveries of this compound in the LCS and LCSD were within control limits, which suggests that the outliers in the MS and MSD may have been caused by matrix effects.

For the PCB samples, a few of the QC criteria were not met for one sample on one of the two columns. Data are reported from the column that met the criteria. The data were determined to be acceptable.

Metals Data

For metals, a few QC criteria were not met for MS, MSD, LCSD, and serial dilution. For two of the samples, the case narrative states that all acceptance criteria for accuracy were met for MS and MSD except for antimony. Results of an analytical post digestion were acceptable, indicating that the matrix had not significantly affected quantitation of this analyte. Lead results were determined from diluted samples. The data were determined to be usable.

Radiological Data

For the gross alpha and gross beta analyses, all QC criteria were met, and the data were determined to be acceptable. Because of insufficient sample volume for tritium, MS analysis was not performed. Other QC criteria were met, though, and the data were determined to be acceptable. For isotopic uranium, most QC criteria were met. In one data package, analysis of a batch duplicate was performed on a sample from another batch. However, data were considered to be acceptable. For gamma spectroscopy and strontium-90 analysis, most QC criteria were met, and the data were acceptable.

3.11.4.2 Groundwater Samples

VOC Data

For VOCs, all QC criteria were met, and the data were considered acceptable.

SVOC/PCB/Pesticide Data

For SVOCs, nearly all QC criteria were met, with the exception of two compounds found in both blank samples and samples from ANL-E (in one data package). The data were considered acceptable. For PCBs, nearly all QC criteria were met, and the data were considered usable.

For pesticides, all QC criteria were met, however, because of insufficient sample volume in both data packages reviewed, LCS and LCSD analyses were performed rather than MS analysis. LCS and LCSD data met the applicable criteria, and the data were considered acceptable.

Metals and Inorganics Data

For metals, all QC criteria and holding times were met, and the data were considered acceptable. For inorganics (including reactive cyanide, reactive sulfide, chloride, nitrate [as N], sulfate, and sulfide), nearly all QC criteria were met. Accurate MS and MSD determinations were not possible for chloride and sulfate because concentration of these analytes in the native sample were above their analytical range on the ion chromatograph. The spike added was small relative to the unspiked sample concentrations. The data were considered acceptable.

For total organic halides and total organic carbon, most QC criteria were met, and the data were judged to be usable.

Radiological Data

For gross alpha and gross beta analysis, all sample results were considered to be usable. However, in one instance, the criterion for minimum detectable concentration was not met for alpha measurements because of insufficient sample volume, and in another instance, the minimum detectable concentration criterion was not met because of elevated levels of dissolved and suspended solids in the samples.

For tritium analysis, all QC criteria were met, and the data were considered acceptable.

For isotopic uranium analysis, most QC criteria were met, and the data were considered acceptable. In one data package, minimum detectable concentration criteria could not be met. In another, insufficient sample volume required that a LCSD be prepared in lieu of a prep batch duplicate.

For gamma spectroscopy analysis, all data were determined to be usable. However, in one data package not all QC criteria were met because of low values for gamma spectroscopy in ANL-E field samples. In another data package, DER criteria were not met, and data are flagged with a “W” for warning.

For strontium-90 analysis, nearly all QC criteria were met and the data were considered acceptable.

4 SITE GEOLOGY AND HYDROGEOLOGY

4.1 INTRODUCTION

Soil boring data generated during this investigation were used to characterize the lithology and hydrogeology under SWMU No. 150. These data were used to create two cross-sections normal to one another. The cross sections are oriented east-west and north-south. Figure 4.1 shows the location of each cross section and of soil borings and monitoring wells used in the characterization of site stratigraphy. Figures 4.2 and 4.3 show the individual cross sections. Detailed soil boring logs are presented in Appendix E.

In addition to the soil boring data, water level data from monitoring wells installed during this investigation were used to better define groundwater occurrence and flow direction beneath SWMU No. 150. Water level data from monitoring wells are presented in Figures 4.2 and 4.3 (geologic cross sections AA′ and BB′). Figure 4.4 is a potentiometric map of the groundwater surface using data from the shallow wells installed at the SWMU. The deeper water-bearing zone was not present in a consistent manner at SWMU No. 150; therefore, a potentiometric map was not developed for this water-bearing unit.

4.2 SITE GEOLOGY RESULTS

In general, geologic data gathered from the drilling and sampling program at SWMU No. 150 correlate well with the descriptions of regional geologic conditions provided in Section 2.2. The study area is underlain by a heterogeneous sequence of clastic glacial deposits. Although these glacial deposits consist primarily of less-permeable, fine-grained sediments (silt and clay), thin deposits of courser-grained sediments (silty sand to gravel) are present throughout the soil column. Soil samples collected during the investigation of SWMU No. 150 were classified by a qualified licensed professional geologist in accordance with the Unified Soil Classification System (USCS). USCS classifications are provided for each unit shown in Figures 4.2 and 4.3.

Geologic cross section AA′ (Figure 4.2) extends in a west-to-east direction from a point about 250 ft northwest of SWMU No. 150 to about 175 ft east of the SWMU. Overall surface elevations remain essentially unchanged, at about 671 ft amsl. A relatively thick porous unit consisting of sand and gravel is present in the central (beneath SWMU No. 150) to eastern portions of this cross section at a depth of 653–658 ft amsl. This unit ranges in thickness from about 2 to about 6 ft. A thinner (about 1-ft-thick) porous unit consisting of sand is present below this unit in the central portion of cross section AA′ at a depth of 642–643 ft amsl. Clay is the predominant lithological unit identified in the western part of the cross section, with no courser-grained porous zones identified.

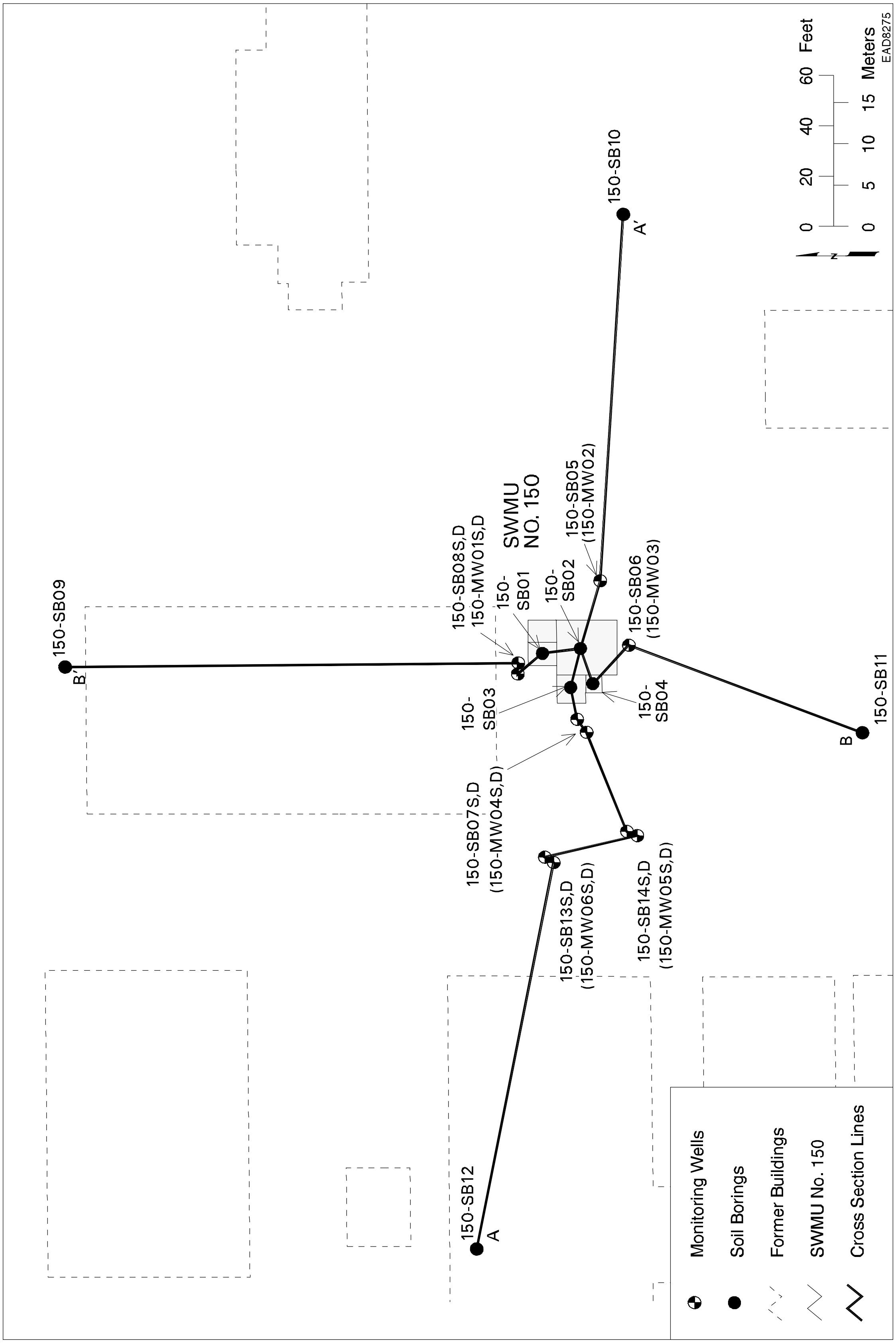


FIGURE 4.1 Locations of Cross Sections, Soil Borings, and Monitoring Wells Used to Characterize Site Stratigraphy

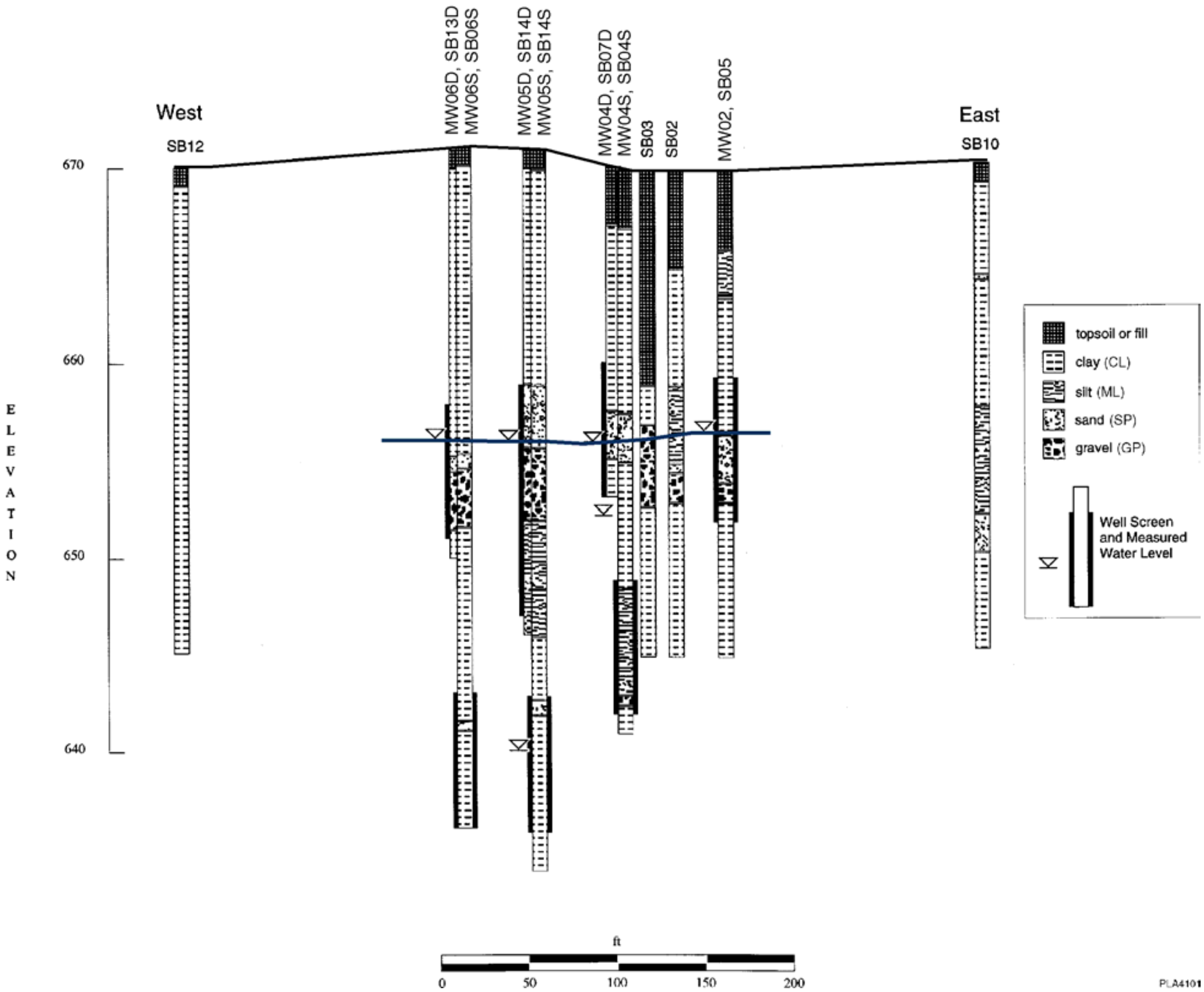


FIGURE 4.2 Cross Section AA′

Geologic cross-section BB′ (Figure 4.3) extends in a south-to-north direction from a point about 100 ft southwest of SWMU No. 150 to about 190 ft north of the unit. Overall surface elevation decreases slightly — from about 671 ft amsl at the south end of the cross section to about 669 ft amsl at the north end. This cross section is generally consistent with cross section AA′. A porous unit consisting of sand and gravel is present in the central (beneath SWMU No. 150) to northern portions of cross section BB′ at a depth of 656–657 ft amsl. This unit ranges in thickness from about 2 to about 8 ft. Beneath SWMU No. 150, the gravel component of the porous unit is common and pinches out until north of SWMU No. 150, where sand characterizes the porous unit. Clay is the predominant lithological unit identified in the southern part of the cross section, with no courser-grained porous zones identified.

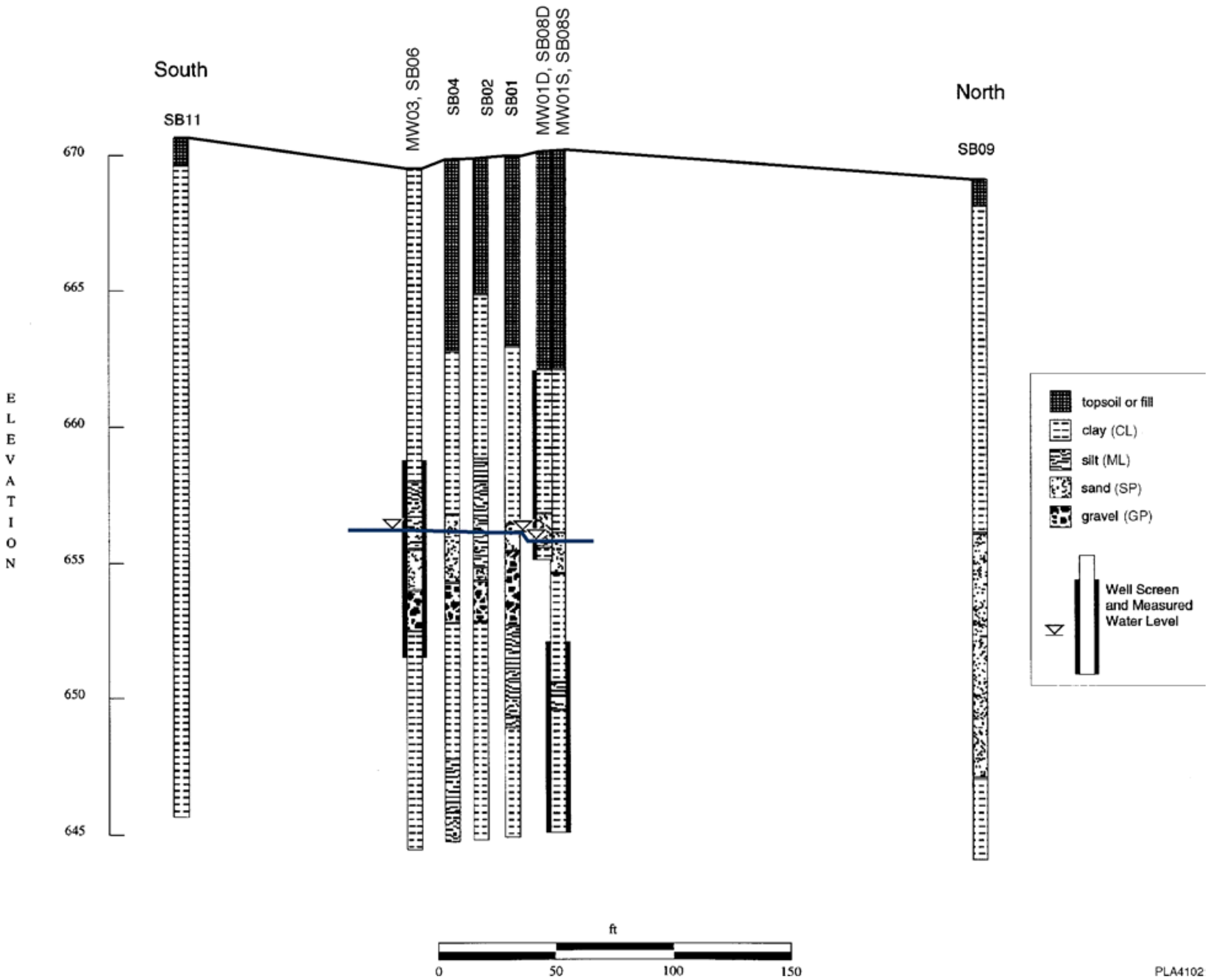


FIGURE 4.3 Cross Section BB′

4.3 SITE HYDROGEOLOGY RESULTS

In general, data for this evaluation were collected from soil boring and monitoring well installation and subsequent monitoring well water level measurements. Groundwater data were collected from a total of 10 monitoring wells installed in the vicinity of SWMU No. 150. The number and depth of wells were based on a review of soil stratigraphic data. When more than one water-bearing zone was encountered, a second well was installed. To avoid confusion, the deeper of the two wells was labeled with a “D” after the well number; the shallower well was labeled with an “S.” In two instances (150-MW02 and 150-MW03), only the shallower, porous water-bearing zone was encountered, and therefore, only one monitoring well was installed. At these locations, no letter designation was used for the well.

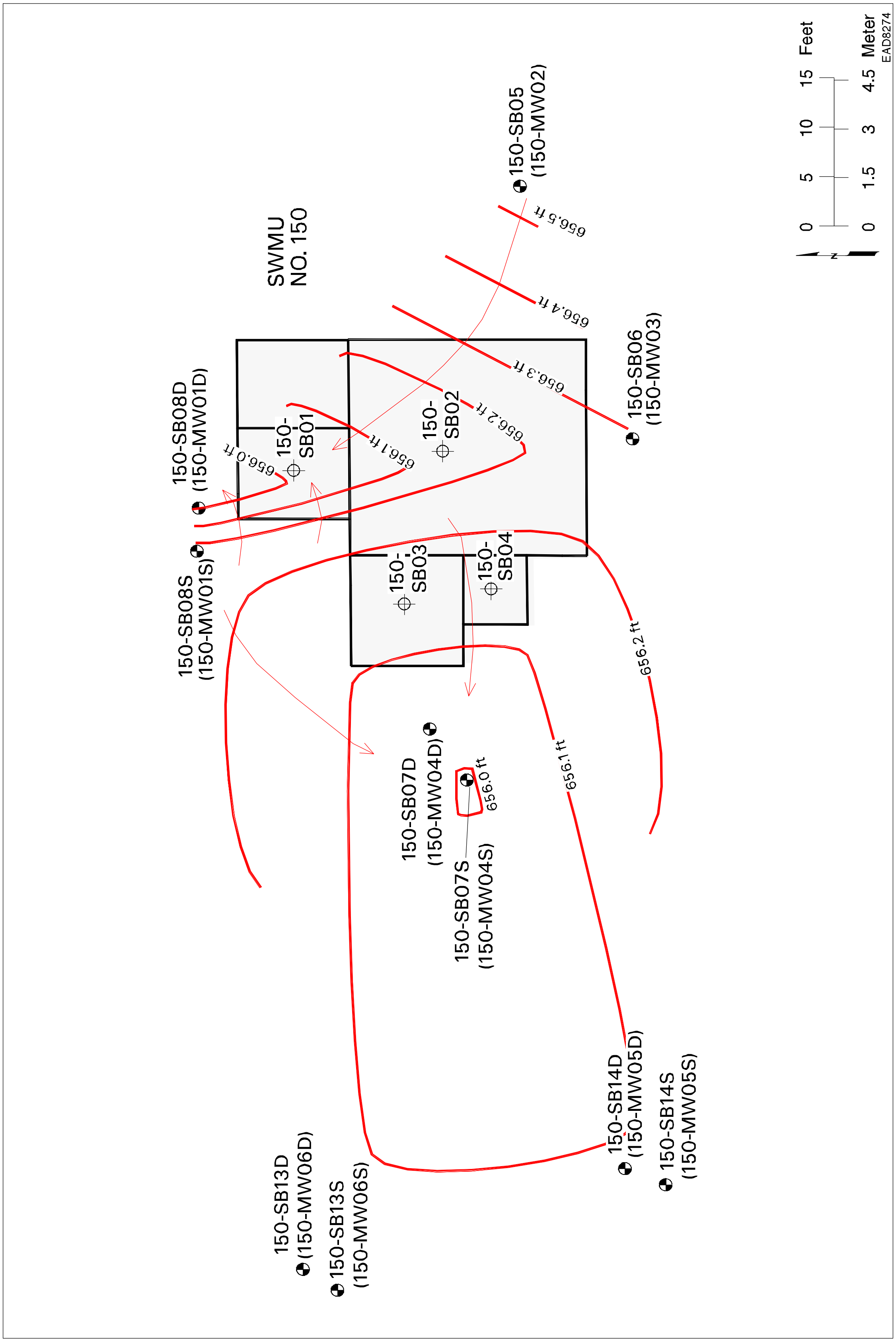


FIGURE 4.4 Potentiometric Map

At SWMU No. 150, water level measurements collected from the "shallow" wells were used to produce a potentiometric map of the groundwater surface. Figure 4.4 illustrates that the groundwater surface slopes under a very slight gradient to the west-northwest. Although this gradient is slight, it does support the notion (ANL 2000a) that Sawmill Creek, located about 900 ft west of SWMU No. 150, forms a natural outlet for water from the shallow sand and gravel water-bearing zone present under SWMU No. 150 as well as other parts of the East Area. The slight northern component to the groundwater flow, notable on the north side of the former Building 34, can be attributed to unconsolidated fill materials added during demolition of Building 34. It is probably a local feature. The discontinuous nature of the "deeper" porous zone in the vicinity of SWMU No. 150 prevented the collection of sufficient well data to allow groundwater surface mapping of this deeper zone.

5 SAMPLING RESULTS

The following subsections discuss analytical results for soil and groundwater samples collected during the investigation of SWMU No. 150. An intensive program of soil boring, subsurface soil sampling, monitoring well installation, and groundwater sampling was conducted in and around the former Building 34 – Liquid Mixed Waste Treatment. The results of this sampling effort are discussed in Sections 5.1 and 5.2.

Contaminant concentrations in soil were compared with either the 95% upper tolerance limit (UTL) of the ANL-E background sample results (also called the background levels) or with TACO Tier 1 cleanup objectives. The background values used for metals were derived from analysis of numerous subsurface soil samples collected throughout the ANL-E site, as presented in the *RCRA Facility Investigation Report, 317/319/ENE Area*, which was submitted to the IEPA in 1997 (ANL 1997). Background values also were derived from 95% UTLs calculated for specific background subsurface soil collected for SWMU No. 133, which is located about 1,500 feet southwest of SWMU No. 150. The 11 soil borings from which the background samples for SWMU No. 133 were collected were drilled and sampled using procedures identical to those used for the SWMU No. 150 soil borings. For this report, the higher of the two 95% UTL values for each metal was used, as permitted by TACO (35 IAC 742 Subpart D).

Where applicable, ANL-E applied values for the Class I Soil Component of the Groundwater Ingestion Exposure Route, or values for the Industrial/Commercial Worker Ingestion or Inhalation Route, or for the Construction Worker Ingestion or Inhalation Route. These values are contained in Tables B and C of Appendix B of TACO. In all cases, the lowest TACO standard or the 95% UTL (if this value was greater than the lowest TACO value) was applied for comparative purposes, as appropriate. Results of radiological analysis of soils were compared with the SWMU No. 133 area background 95% UTL values, which were derived from the same pool of samples used to develop the SROs discussed above.

For groundwater, VOC, semivolatile organic compound (SVOC), and PCB/pesticide results were compared with GROs found in TACO Tier 1, Table E, Appendix B (GROs for the Groundwater Ingestion Exposure Route, Class I Groundwater). Results for miscellaneous parameters were compared to other GROs listed in TACO (Tier 1, Table E, Appendix B) or to background values contained in the *RCRA Facility Investigation Report for the 317/319/ENE Area* (ANL 1997). Results of radiological analysis of groundwater samples were compared with the highest value detected in the upgradient, or background, well. Tritium levels were compared with the IEPA drinking water standard. (It should be noted that the metals results for groundwater samples from the third through the fifth rounds of sampling show several more constituents than in the first two rounds of sampling. This difference is the result of an administrative change in reporting by the analytical laboratory. For the last three rounds of groundwater sampling, metals results were reported along with the analytical MDL, rather than the analytical laboratory practical quantitation limit [PQL] [i.e., the reporting limit used in the first two rounds of sampling]. In all cases, the MDL, which is determined by IEPA-accepted SW-846 [third edition procedures], is lower than the PQL.)

5.1 SUBSURFACE SOIL SAMPLE RESULTS

A total of 107 soil samples were collected from 10 soil borings. All soil borings were drilled to a depth of 25 ft bgs, and soil samples were collected for VOC analysis on a continual basis. At the conclusion of each boring, a composite sample was prepared. Composite samples were collected from eight soil borings and analyzed for metals, SVOCs, pesticides/PCBs, and radioactivity, including gross alpha, gross beta, gamma spectroscopy, isotopic uranium, strontium-90, and tritium. At two soil borings, a total of three soil samples were collected from water-bearing zones prior to well installation. These samples were analyzed for metals only. Composite samples were not collected from these two boreholes.

5.1.1 VOCs

Table 5.1 presents the detectable concentrations of VOCs in the subsurface soils. A total of 14 VOCs were detected in the subsurface soil samples, but all concentrations were found to be below their respective SROs.

5.1.2 Metals

Metals concentrations in the composite subsurface soil samples are listed in Table 5.2. A total of 12 metals were detected in the composite soil samples. Three metals were found to exceed their SROs by slight amounts. Arsenic was present in the composite sample from boring 150-SB06 at a concentration of 22 mg/kg, which exceeds its SRO of 19.7 mg/kg. Tin was present in the composite sample from boring 150-SB07 at a concentration of 7.5 mg/kg, which exceeds its SRO of 6.975 mg/kg. Thallium was present at a concentration of 2.4 mg/kg — above its SRO of 2.3 mg/kg — in the composite soil sample from boring 150-SB06. All other metals were detected at concentrations below their respective SROs.

The arsenic, tin, and thallium present in soil borings 150-SB06 and 150-SB07 were addressed by using averaging techniques provided in TACO [35 IAC 742.225(d)]. The ingestion exposure pathway cleanup objective assumes that an on-site worker will receive a chronic dose of contaminant by being exposed to the contaminated soils each workday. Comparing the SRO to an individual data point would skew the comparison toward an overly conservative conclusion because it is unlikely that an on-site worker would be exposed to the same location each day. Therefore, we determined that the averaged result of several samples collected in the vicinity of SWMU No. 150 would represent the average exposure concentration for the SWMU No. 150 area better than a single grab sample. These averaged values would then be compared to the SROs for arsenic, tin, and thallium. If the averaged results were less than the respective SROs, an NFA request based on conformance with the Tier 1 standards would be submitted.

For arsenic, the analysis results for the composite soil samples indicated arsenic concentrations ranging from 6.6 to 22 mg/kg. The resulting average arsenic concentration, which

TABLE 5.1 VOC Concentrations in Subsurface Soils[a,b]

Sample Location	ANL150-SB01													
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(13-15)	(15-17)	(17-19)	(19-21)	(21-23)	(23-25)DUP	(23-25)	SRO[c]
Date Collected	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	
Acetone	19U	19U	20U	19U	19U	18U	22U	17U	17U	17U	20U	24U	21U	16,000[d]
Methylene chloride	2.5JB	2.3JB	2.3JB	2.1JB	2JB	1.2JB	1.6JB	2.1JB	1.9JB	1.3JB	2.1JB	8.2B	2.1JB	20[d]
Naphthalene	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	0.89J	4.1U	4.2U	4.9U	5.9U	5.1U	84,000[d]
1,1-Dichloroethane	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	23,000[d]
1,1,1-Trichloroethane	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	2,000[d]
Benzene	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	30[d]
1,2-Dichloroethane	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	20[d]
Trichloroethene	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	60[d]
Trichlorofluoromethane	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	-
Cis-1,2-dichloroethene	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	400[d]
Tetrachloroethene	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	60[d]
Trans-1,2-dichloroethene	4.7U	4.8U	5.1U	4.7U	4.7U	4.6U	5.4U	4.4U	4.1U	4.2U	4.9U	5.9U	5.1U	700[d]
4-methyl-2-pentanone	19U	19U	20U	19U	19U	18U	22U	17U	17U	17U	20U	24U	21U	-
Acrylonitrile	47U	48U	51U	47U	47U	46U	54U	44U	41U	42U	49U	59U	51U	-
2-Butanone	19U	19U	20U	19U	19U	18U	22U	17U	17U	17U	20U	24U	21U	-

Sample Location	ANL150-SB02												
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(13-15)	(15-17)	(17-19)	(19-21)	(21-23)	(23-25)	SRO[c]
Date Collected	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	11/23/99	
Acetone	19U	34U	21U	19U	19U	18U	8.6J	20U	19U	19U	18U	18U	16,000[d]
Methylene chloride	2.2JB	3.1JB	2.4JB	2.2JB	1.4JB	5.6B	1.5JB	1.8JB	6.3B	7.1B	5.1B	4.9B	20[d]
Naphthalene	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	84,000[d]
1,1-Dichloroethane	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	23,000[d]
1,1,1-Trichloroethane	3J	4.4J	14	0.88J	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	2,000[d]
Benzene	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	30[d]
1,2-Dichloroethane	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	20[d]
Trichloroethene	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	60[d]
Trichlorofluoromethane	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	-
Cis-1,2-dichloroethene	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	400[d]
Tetrachloroethene	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	60[d]
Trans-1,2-dichloroethene	4.7U	8.6U	5.2U	4.7U	4.8U	4.4U	4.7U	5.1U	4.8U	4.8U	4.4U	4.4U	700[d]
4-methyl-2-pentanone	19U	34U	21U	19U	19U	18U	2JB	20U	19U	19U	18U	18U	-
Acrylonitrile	47U	86U	52U	47U	48U	44U	7J	51U	48U	48U	44U	44U	-
2-Butanone	19U	34U	21U	19U	19U	18U	6J	20U	19U	19U	18U	18U	-

TABLE 5.1 (Cont.)

Sample Location	ANL150-SB03											
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(15-17)	(17-19)	(19-21)	(21-23)	(23-25)	SRO[c]
Date Collected	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	
Acetone	23U	13J	13J	13J	23U	16J	22U	23U	15J	23U	13J	16,000[d]
Methylene chloride	4.2JB	4.7JB	4.1JB	4.2JB	3.7JB	4.9JB	4.1JB	3.6JB	3.7JB	3.6JB	4.6JB	20[d]
Naphthalene	5.6U	5.6U	5.9U	5.8U	5.7U	6.2U	5.6U	5.7U	5.8U	5.8U	5.8U	84,000[d]
1,1-Dichloroethane	5.6U	5.6U	5.9U	5.8U	4.3J	15	9.9	5.7U	5.8U	5.8U	5.8U	23,000[d]
1,1,1-Trichloroethane	5.6U	5.6U	5.9U	5.8U	12	6.2U	28	5.7U	5.8U	5.8U	5.8U	2,000[d]
Benzene	5.6U	5.6U	5.9U	5.8U	0.53J	0.61J	0.6J	5.7U	5.8U	5.8U	0.53J	30[d]
1,2-Dichloroethane	5.6U	5.6U	5.9U	5.8U	5.7U	7.2	4.5J	5.7U	5.8U	5.8U	5.8U	20[d]
Trichloroethene	5.6U	5.6U	5.9U	5.8U	19	0.9J	8.9	5.7U	5.8U	5.8U	5.8U	60[d]
Trichlorofluoromethane	5.6U	0.86J	5.9U	5.8U	5.7U	6.2U	5.6U	5.7U	5.8U	5.8U	5.8U	-
Cis-1,2-dichloroethene	5.6U	5.6U	5.9U	5.8U	14	8.8	4J	5.7U	5.8U	5.8U	5.8U	400[d]
Tetrachloroethene	5.6U	5.6U	5.9U	5.8U	1.3J	6.2U	1J	5.7U	5.8U	5.8U	5.8U	60[d]
Trans-1,2-dichloroethene	5.6U	5.6U	5.9U	5.8U	5.7U	1.2J	5.6U	5.7U	5.8U	5.8U	5.8U	700[d]
4-methyl-2-pentanone	23U	22U	23U	23U	23U	3.4J	22U	23U	23U	23U	23U	-
Acrylonitrile	56U	56U	59U	58U	57U	62U	56U	57U	58U	58U	58U	-
2-Butanone	23U	22U	23U	23U	23U	25U	22U	23U	23U	23U	23U	-

Sample Location	ANL150-SB04												
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(13-15)	(15-17)	(17-19)	(19-21)	(21-23)	(23-25)	SRO[c]
Date Collected	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	11/19/99	
Acetone	18U	18U	19U	18U	17U	6.78J	20U	15J	18.1U	17U	19U	22.6U	16,000[d]
Methylene chloride	16B	11B	9.2B	17B	15B	2.7JB	21B	22B	2.32JB	10B	11B	3.01JB	20[d]
Naphthalene	0.71JB	0.91JB	4.8U	4.4U	4.3U	1.07JB	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	84,000[d]
1,1-Dichloroethane	4.6U	4.5U	4.8U	4.4U	1.6J	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	23,000[d]
1,1,1-Trichloroethane	4.6U	4.5U	4.8U	4.4U	7.3	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	2,000[d]
Benzene	4.6U	4.5U	4.8U	4.4U	4.3U	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	30[d]
1,2-Dichloroethane	4.6U	4.5U	4.8U	4.4U	4.3U	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	20[d]
Trichloroethene	4.6U	4.5U	4.8U	4.4U	4.3U	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	60[d]
Trichlorofluoromethane	4.6U	4.5U	4.8U	4.4U	4.3U	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	-
Cis-1,2-dichloroethene	4.6U	4.5U	4.8U	4.4U	4.3U	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	400[d]
Tetrachloroethene	4.6U	4.5U	4.8U	4.4U	4.3U	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	60[d]
Trans-1,2-dichloroethene	4.6U	4.5U	4.8U	4.4U	4.3U	4.28U	4.9U	5.6U	4.52U	4.3U	4.7U	5.65U	700[d]
4-methyl-2-pentanone	18U	18U	19U	18U	17U	17.1U	20U	22U	18.1U	17U	19U	22.6U	-
Acrylonitrile	46U	45U	48U	44U	43U	42.8U	49U	56U	45.2U	43U	47U	56.5U	-
2-Butanone	18U	18U	19U	18U	17U	17.1U	20U	22U	18.1U	17U	19U	22.6U	-

TABLE 5.1 (Cont.)

Sample Location	ANL150-SB05												
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(13-15)	(15-17)	(17-19)	(19-21)	(21-23)	(23-25)	SRO[c]
Date Collected	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	11/16/99	
Acetone	18U	18U	21U	20U	19U	20U	20U	19U	19U	18U	20U	19U	16,000[d]
Methylene chloride	3.9JB	4.4JB	3.3JB	3JB	3.1JB	3JB	3JB	3.6JB	3.3JB	2.5JB	3.1JB	3.2JB	20[d]
Naphthalene	4.5U	4.5U	1.3JB	0.8JB	0.76JB	5.1U	1JB	4.8U	4.6U	4.5U	5.1U	4.7U	84,000[d]
1,1-Dichloroethane	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	23,000[d]
1,1,1-Trichloroethane	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	2,000[d]
Benzene	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	30[d]
1,2-Dichloroethane	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	20[d]
Trichloroethene	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	60[d]
Trichlorofluoromethane	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	-
Cis-1,2-dichloroethene	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	400[d]
Tetrachloroethene	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	60[d]
Trans-1,2-dichloroethene	4.5U	4.5U	5.2U	5U	4.8JB	5.1U	5.1U	4.8U	4.6U	4.5U	5.1U	4.7U	700[d]
4-methyl-2-pentanone	18U	18U	21U	20U	19U	20U	20U	19U	19U	18U	20U	19U	-
Acrylonitrile	45U	45U	52U	50U	48U	51U	51U	48U	46U	45U	51U	47U	-
2-Butanone	18U	18U	21U	20U	19U	20U	20U	19U	19U	18U	20U	19U	-

Sample Location	ANL150-SB06												
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(13-15)	(15-17)	(17-19)	(19-21)	(21-23)	(23-25)	SRO[c]
Date Collected	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	11/17/99	
Acetone	19U	21U	23U	19U	20U	17U	21U	30JB	9.5J	16U	18U	20U	16,000[d]
Methylene chloride	3.3JB	3.6JB	4.8JB	3.4JB	3.5JB	2.3JB	3.4JB	4.5JB	2.7JB	2.2JB	2.5JB	2.9JB	20[d]
Naphthalene	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	84,000[d]
1,1-Dichloroethane	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	23,000[d]
1,1,1-Trichloroethane	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	2,000[d]
Benzene	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	0.95JB	4.7U	4.1U	4.5U	4.9U	30[d]
1,2-Dichloroethane	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	20[d]
Trichloroethene	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	60[d]
Trichlorofluoromethane	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	-
Cis-1,2-dichloroethene	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	400[d]
Tetrachloroethene	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	60[d]
Trans-1,2-dichloroethene	4.8U	5.2U	5.8U	4.8U	4.9U	4.4U	5.2U	8.1U	4.7U	4.1U	4.5U	4.9U	700[d]
4-methyl-2-pentanone	19U	21U	23U	19U	20U	17U	21U	32U	19U	16U	18U	20U	-
Acrylonitrile	48U	52U	58U	48U	49U	44U	52U	81U	47U	41U	45U	49U	-
2-Butanone	19U	21U	23U	19U	20U	17U	21U	32U	19U	16U	18U	20U	-

TABLE 5.1 (Cont.)

Sample Location	ANL150-SB07												
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(13-15)	(15-17)	(19-21)	(21-23)	(23-25)	(27-29)	SRO[c]
Date Collected	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	11/18/99	
Acetone	20JB	17JB	21JB	21JB	25U	17JB	23U	22JB	17JB	19JB	15JB	15J	16,000[d]
Methylene chloride	3.2JB	4.3JB	3.6JB	3.6JB	4JB	4.4JB	4.4JB	3.3JB	3.3JB	3.7JB	3.5JB	3.8JB	20[d]
Naphthalene	5.7U	5.6U	5.9U	5.8U	6.3U	5.8U	5.8U	5.8U	5.6U	5.9U	6U	5.9U	84,000[d]
1,1-Dichloroethane	5.7U	5.6U	5.9U	1.8J	6.3U	6.1	2.1J	14	5.6U	5.9U	6U	5.9U	23,000[d]
1,1,1-Trichloroethane	5.7U	5.6U	5.9U	0.91J	6.3U	11	70	6.2	5.6U	5.9U	6U	5.9U	2,000[d]
Benzene	0.56JB	0.69JB	0.69JB	0.62JB	6.3U	0.61JB	5.8U	0.67JB	5.6U	0.69JB	0.63JB	5.9U	30[d]
1,2-Dichloroethane	5.7U	5.6U	5.9U	5.8U	6.3U	1.9J	5.8U	1J	5.6U	5.9U	6U	5.9U	20[d]
Trichloroethene	5.7U	5.6U	5.9U	5.8U	6.3U	0.44J	5.8U	1.3J	5.6U	5.9U	6U	5.9U	60[d]
Trichlorofluoromethane	5.7U	5.6U	5.9U	5.8U	6.3U	5.8U	5.8U	5.8U	5.6U	5.9U	6U	5.9U	-
Cis-1,2-dichloroethene	5.7U	5.6U	5.9U	5.8U	6.3U	5.8U	5.8U	5.8U	5.6U	5.9U	6U	5.9U	400[d]
Tetrachloroethene	5.7U	5.6U	5.9U	5.8U	6.3U	5.8U	5.8U	5.8U	5.6U	5.9U	6U	5.9U	60[d]
Trans-1,2-dichloroethene	5.7U	5.6U	5.9U	5.8U	6.3U	5.8U	5.8U	5.8U	5.6U	5.9U	6U	5.9U	700[d]
4-methyl-2-pentanone	23U	22U	23U	23U	25U	23U	23U	23U	23U	24U	24U	24U	-
Acrylonitrile	57U	56U	59U	58U	63U	58U	58U	58U	56U	59U	60U	59U	-
2-Butanone	23U	22U	23U	23U	25U	23U	23U	23U	23U	24U	24U	24U	-

Sample Location	ANL150-SB08													
Depth (ft)	(1-3)	(3-5)	(5-7)	(7-9)	(9-11)	(11-13)	(13-15)	(15-17)	(17-19)	(19-21)	(21-23)	(23-25)	(23-25)	SRO[c]
Date Collected	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/15/99	11/17/99	
Acetone	17U	8.4J	24J	13J	11J	18U	21U	17U	17U	38U	19U	18U		16,000[d]
Methylene chloride	2.9JB	12B	22B	8.6B	8B	8.6B	3.7JB	3.5JB	2.9JB	7.3JB	3.4JB	2.8JB	2.9JB	20[d]
Naphthalene	1.9JB	1.2JB	1.9JB	0.78JB	4.6U	4.4U	0.8JB	4.3U	4.2U	9.6U	4.7U	4.6U		84,000[d]
1,1-Dichloroethane	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		23,000[d]
1,1,1-Trichloroethane	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		2,000[d]
Benzene	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		30[d]
1,2-Dichloroethane	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		20[d]
Trichloroethene	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		60[d]
Trichlorofluoromethane	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		-
Cis-1,2-dichloroethene	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		400[d]
Tetrachloroethene	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		60[d]
Trans-1,2-dichloroethene	4.2U	5.5U	8.4U	4.8U	4.6U	4.4U	5.2U	4.3U	4.2U	9.6U	4.7U	4.6U		700[d]
4-methyl-2-pentanone	17U	22U	33U	19U	18U	18U	21U	17U	17U	38U	19U	18U		-
Acrylonitrile	42U	55U	84U	48U	46U	44U	52U	43U	42U	96U	47U	46U		-
2-Butanone	17U	22U	33U	19U	18U	18U	21U	17U	17U	38U	19U	18U		-

[a] Concentrations are in mg/kg.

[b] A hyphen indicates that no SRO exists for this compound. B = compound also found in associated laboratory method blank. J = estimated value, below detection limit. U = undetected; value shown is the detection limit.

[c] SRO derived from Table B, Appendix B, IEPA TACO Guidance (35 IAC 742).

[d] Table B, Appendix B, IEPA TACO Guidance (35 IAC 742), Soil Component of the Groundwater Ingestion Route, Class I Groundwater.

TABLE 5.2 Metals Concentrations in Subsurface Soils[a,b]

Sample Location	150-SB01-COMP	150-SB02-COMP	150-SB03-COMP	150-SB04-COMP	150-SB05-COMP	150-SB06-COMP	SRO[c]
Date Collected	11/23/99	11/23/99	11/18/99	11/19/99	11/16/99	11/17/99	
Arsenic	8.2	8.1	9.1	19	6.6	**22**	19.7[d]
Barium	17	37	46	53	35	55	2,100[e]
Chromium	9.2	14	21	13	14	14	28[f]
Cobalt	7	9.5	11	8.7	9.3	12	12,000[f]
Copper	19	22	29	23	20	30	8,200[f]
Lead	11	11	19	15	11	17	400[f]
Nickel	18	25	26	21	24	34	3,800[e]
Selenium	0.54U	0.59U	0.67	1.1U	0.56U	1.1U	2.4[e]
Tin	5.4	5U	6.9	6.1	5.6U	6.6	6.975[g]
Vanadium	11	16	18	18	17	18	980[e]
Thallium	1.1U	1.2U	1.2U	2.2U	1.1U	**2.4**	2.3[g]
Zinc	36	49	70	79	47	60	53,000[e]

Sample Location	150-SB07-COMP	150-SB08-COMP	SRO[c]
Date Collected	11/18/99	11/15/99	
Arsenic	8.4	13	19.7[d]
Barium	31	50	2,100[e]
Chromium	11	15	28[f]
Cobalt	6.4	9.4	12,000[f]
Copper	21	21	8,200[f]
Lead	12	14	400[f]
Nickel	16	24	3,800[e]
Selenium	0.58U	1.1U	2.4[e]
Tin	**7.5**	6.5	6.975[g]
Vanadium	13	17	980[e]
Thallium	1.2U	2.3U	2.3[g]
Zinc	44	53	53,000[e]

[a] Concentrations in mg/kg.

[b] Bold indicates that the level exceeds the SRO. U = undetected; value shown is the detection limit.

[c] SRO is either the TACO Tier 1 value, the SWMU No. 133 background 95% UTL, or the ANL-E sitewide 95% UTL.

[d] ANL-E sitewide 95% UTL.

[e] Table C, Appendix B, IEPA TACO Guidance (35 IAC 742), pH 7.75 to 8.

[f] Table B, Appendix B, IEPA TACO Guidance (35 IAC 742), Construction Worker Ingestion Route.

[g] 95% UTL derived from SWMU No. 133 background soil samples.

was derived from a total of seven soil boring locations, was 11.8 mg/kg. This value, which is representative of the soil conditions in and around SWMU No. 150 as a whole, is well below the SRO of 19.7 mg/kg, which is based on background values. This finding indicates that the levels found are consistent with normal background levels. Similarly, for tin and thallium, the resulting average concentrations from the eight soil borings were 6.2 mg/kg tin and 1.6 mg/kg thallium. These concentrations are also below their background-based SROs of 6.975 mg/kg (tin) and 2.3 mg/kg (thallium) and are also consistent with background values.

5.1.3 SVOCs

Estimated concentrations of only four SVOCs were detected in one composite subsurface soil sample. However, all SVOC concentrations detected were well below their respective SROs. At boring location 150-SB08, estimated concentrations of bis(2-ethylhexyl)phthalate (0.300 mg/kg), fluoranthene (0.190 mg/kg), phenanthrene (0.240 mg/kg), and pyrene (0.170 mg/kg) were present in the sample. No other SVOCs were detected.

5.1.4 Pesticides/PCBs

Two pesticides were detected in one composite soil sample at concentrations below their SROs. 4,4-DDE and 4,4-DDT were found to be present in the sample from soil boring 150-SB04 at concentrations of 0.0066 mg/kg and 0.0058 mg/kg, respectively. Aroclor-1254 was the only PCB detected and was present at a concentration of 0.086 mg/kg at soil boring 150-SB03. In both cases, the concentrations of pesticides and PCBs were below their respective SROs.

5.1.5 Radionuclides

Concentrations of gross alpha and gross beta activity were detected above their respective background values of 6.75 ± 1.6 and 4.9 ± 1.5 at seven soil boring locations. The maximum gross alpha value (18.2 ± 6.3) and gross beta value (12.3 ± 3.3) were both detected at boring 150-SB04. This boring was located in the center of the former acid tank on the west side of the building. These levels are slightly above ANL-E background levels for gross alpha and gross beta activity and are probably related to detectable levels of uranium isotopes, discussed below.

Uranium isotopes (U-234, U-235, and U-238) were the only radionuclides detected in the subsurface soil samples. Although these isotopes are naturally occurring, they were found to be present in the subsurface soil samples at levels exceeding their respective background values. U-234 was present at only one soil boring in excess of its SRO. At 150-SB03, this isotope was present at a concentration of 1.5 pCi/g, which is generally slightly above, but within the range of uncertainty of its SRO. U-235 was present in all composite soil samples above the background value of 0.0885 pCi/g. At soil borings 150-SB01, 150-SB02, 150-SB03, and 150-SB04, this isotope was present at levels about two to three times its background level. These locations correspond to former waste treatment tanks and other parts of the former Building 34 interior. At the other boring locations where composite soil samples were collected (150-SB05, 150-SB06, 150-SB07, and 150-SB08), U-235 was present at lower levels (0.124, 0.106, 0.102, and 0.099 pCi/g), generally slightly above, but within the range of uncertainty of its SRO. U-238 was present at concentrations in excess of its background level at four soil boring locations (150-SB03, 150-SB04, 150-SB05, and 150-SB08), but these levels were generally slightly above, but within the range of uncertainty of the background value for this isotope.

In general, most of the radionuclides present at concentrations in excess of their background values were collected from soil borings at the former locations of the acid and metals tanks, on the west side of the former Building 34; fewer radionuclides were present and at lower concentrations at the former cyanide tank (Table 5.3). Their presence in the subsurface soils is coincident with the elevated nickel, chromium, and radionuclides in the shallow groundwater immediately west of these units and may be related to past operation of the former in-ground concrete structures.

TABLE 5.3 Radionuclide Concentrations in Subsurface Soils[a,b]

Sample Location	150-SB01-COMP	150-SB02-COMP	150-SB03-COMP	150-SB04-COMP	Background Values[c]
Date Collected	11/23/99	11/23/99	11/18/99	11/19/99	
Gross alpha	6.4+/-4.9	**13.9+/-6.2**	6.4U	**18.2+/-6.3**	6.75+/-1.6
Gross beta	**5.1+/-2.9**	4.7+/-3.1	5U	**12+/-3.3**	4.9+/-1.5
U-234	1.06+/-0.17	0.92+/-0.16	**1.50+/-0.23**	1.2+/-0.24	1.366+/-0.16
U-235	**0.241+/-0.18**	**0.279+/-0.075**	**0.153+/-0.049**	**0.193+/-0.081**	0.0885+/-0.028
U-238	1.15+/-0.18	1.07+/-0.18	**2.13+/-0.30**	**1.54+/-0.28**	1.195+/-0.165
Sample Location	150-SB05-COMP	150-SB06-COMP	150-SB07-COMP	150-SB08-COMP	
Date Collected	11/16/99	11/17/99	11/18/99	11/15/99	
Gross alpha	**7.4+/-4.7**	**8.8+/-4.7**	**8.0+/-4.9**	**11.1+/-5.2**	6.75+/-1.6
Gross beta	**6.7+/-2.8**	4.0+/-3.0	4.7U	**6.5+/-2.9**	4.9+/-1.5
U-234	1.3+/-0.20	1.02+/-0.16	0.92+/-0.16	1.04+/-0.17	1.366+/-0.16
U-235	**0.124+/-0.045**	**.106+/-0.38**	**0.102+/-0.041**	**.099+/-.037**	0.0885+/-0.028
U-238	**1.66+/-0.25**	1.07+/-0.17	1.11+/-0.18	**1.27+/-0.19**	1.195+/-0.165

[a] Concentrations are in pCi/g.

[b] Bold indicates that the value exceeds the background level. U = undetected; value shown is the detection limit.

[c] Background values derived from the 95% UTLs for local area background soil borings at SWMU No. 133, located about 1,500 ft southwest of SWMU No. 150 (ANL-E 2000a).

5.2 GROUNDWATER SAMPLE RESULTS

A total of 10 groundwater monitoring wells were installed near SWMU No. 150. The locations of these wells are shown in Figure 3.1. The approved Work Plan (ANL 1998) proposed that monitoring wells be installed at five locations. Initially, one well was installed on each side of the former Building 34, with one well serving as a background well. At two locations, separate wells were installed in stratigraphically separate water-bearing zones. Additionally, two well clusters were installed downgradient of the former Building 34 in an effort to delineate metals groundwater contamination found in wells near the former Building 34.

As shown in Figure 4.4, four well locations are downgradient of SWMU No. 150. Monitoring wells 150-MW01S and 150-MW01D were installed as a well cluster about 8 ft north of the former cyanide tank, north of the former Building 34. Monitoring wells 150-MW04S and 150-MW04D were installed about 8 ft west of the former acid tank, west of the former Building 34. These two monitoring well clusters were installed to assess the impact of the former cyanide and acid tanks on the shallow groundwater. Monitoring wells 150-MW05S and 150-MW05D, and 150-MW06S and 150-MW06D were installed as two clusters about 30 ft west of monitoring wells 150-MW04S and 150-MW04D to more accurately delineate the extent of metals contamination found in monitoring wells 150-MW01S, 150-MW04S, and 150-MW04D.

Monitoring well 150-MW02, located about 8 ft east of the east side of the former Building 34, was installed to serve as a background monitoring well. The purpose of the upgradient well was to provide a set of groundwater data representative of upgradient conditions that could be compared with the downgradient groundwater data. Monitoring well 150-MW03 was installed about 8 ft south of the former Building 34 to serve as a side-gradient well, unaffected by SWMU operations. Monitoring wells, with associated soil boring number and well screen intervals, are listed in Table 5.4. Figure 5.1 shows monitoring well locations.

TABLE 5.4 Monitoring Well Screened Intervals

Monitoring Well No.	Soil Boring No.	Screened Interval (ft bgs)	Date Installed
150-MW01S	150-SB08S	9.8-14.8	11/15/99
150-MW01D	150-SB08D	19.8-24.8	11/15/99
150-MW02	150-SB05	12.8-18	11/16/99
150-MW03	150-SB06	12.8-18	11/17/99
150-MW04S	150-SB07S	12-17	11/19/99
150-MW04D	150-SB07D	22.8-28	11/18/99
150-MW05S	150-SB14S	14-24	7/12/00
150-MW05D	150-SB14D	30-35	7/12/00
150-MW06S	150-SB13S	15-20	7/13/00
150-MW06D	150-SB13D	30-35	7/13/00

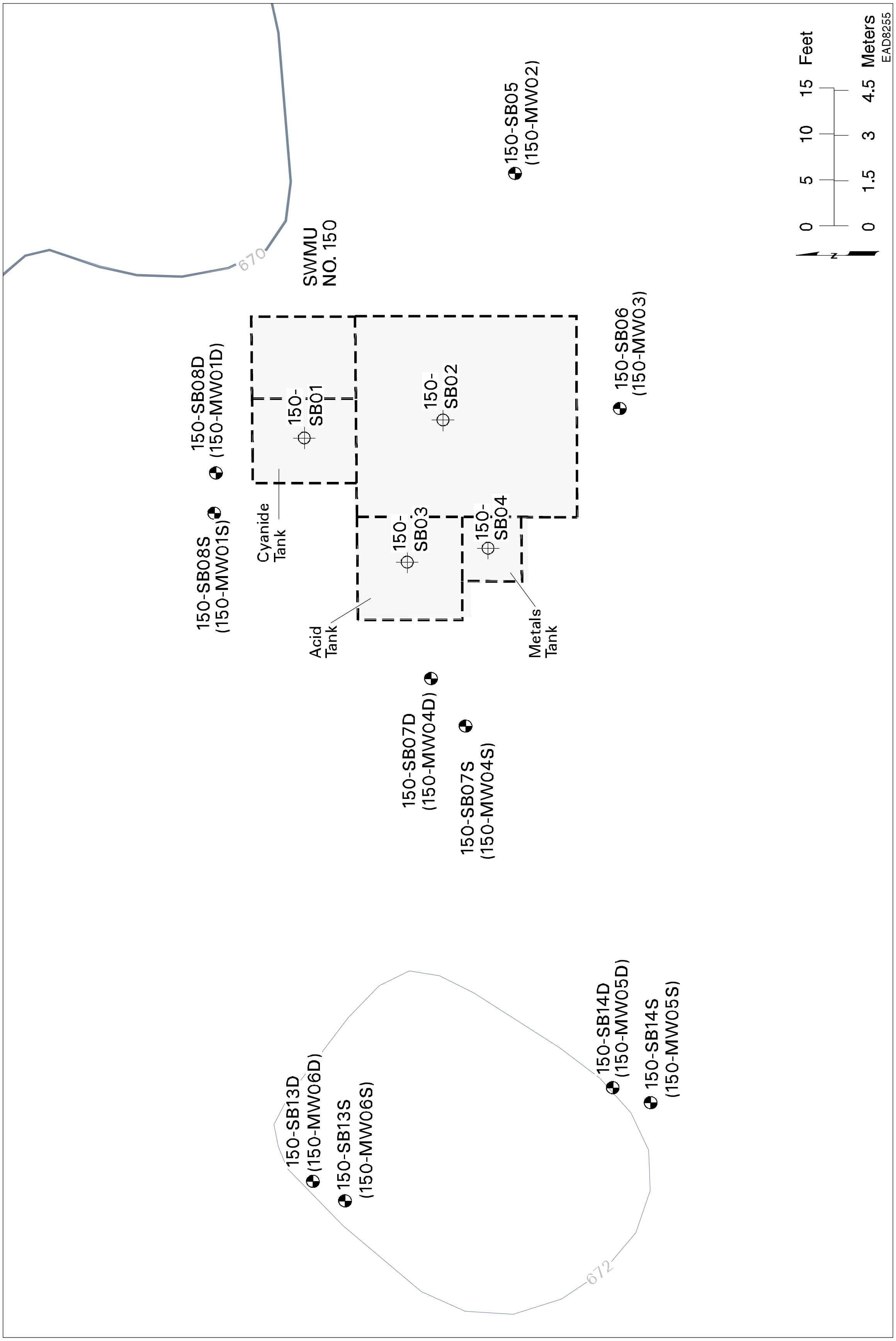


FIGURE 5.1 Monitoring Well Locations

Groundwater samples were collected over five rounds of sampling, as shown in Table 5.5. Monitoring wells 150-MW01S/D and 150-MW04S/D were sampled over five rounds. Monitoring wells 150-MW02 and 150-MW03 were sampled over four rounds, and monitoring wells 150-MW05S/D and 150-MW06S/D were sampled over two rounds. Table 5.5 summarizes each round of sampling and the corresponding analyses. For the first two rounds, groundwater samples were analyzed for total metals, VOCs, SVOCs, pesticides/PCBs, radionuclides, and miscellaneous parameters (including cyanide, sulfide, sulfate, chloride, nitrate, total organic halogens [TOX], and total organic compounds [TOC]). A review of the results of the first two rounds of sampling indicated that metals were the only constituent that exceeded the respective SROs. Therefore, groundwater samples collected during sampling rounds three and four were analyzed for total metals only; and groundwater samples collected during the fifth round of sampling were analyzed for both total and dissolved metals. Groundwater sampling results are discussed in the following sections.

5.2.1 Metals

The detectable levels of total and dissolved metals are listed in Tables 5.6 and 5.7. At four well locations, groundwater samples also were collected for analysis of dissolved metals during the fifth round of sampling.

Sampling rounds 1 and 2 included groundwater sampling for total metals from wells 150-MW01S/D, 150-MW02, 150-MW03, and 150-MW04S/D, as outlined in the approved work plan. In July 2000, additional wells (150-MW05S/D and 150-MW06S/D) were drilled in an effort to delineate the extent of high metals concentrations found in wells 150-MW01S/D and 150-MW04S/D. Two rounds of groundwater samples subsequently were collected for total metals analysis from the wells installed in July 2000. Sampling rounds 3 and 4 also included groundwater sampling for total metals at all wells drilled as part of the approved work plan. Data collected during rounds 3 and 4 were compared to data collected from the two rounds at the additional wells. Because of the continuing presence of elevated nickel and chromium concentrations at wells MW04S/D, a fifth round of sampling was conducted, and the samples were analyzed for both total and dissolved metals. The purpose of the dissolved metals sample analysis was to determine whether elevated levels of metals in the groundwater resulted from suspended soil particles in the water sample, even at the low turbidity values obtained using the MicroPurge™ technique.

5.2.1.1 Total Metals

Metals detected at levels above Tier 1 GROs by total metals analysis included manganese, nickel, chromium, thallium, and iron. Manganese was detected above its GRO of 0.15 mg/L in the fourth round of sampling at well 150-MW01S (0.21 mg/L). At well 150-MW03, manganese was detected above its GRO in the second, third, and fourth rounds of groundwater sampling, at concentrations of 0.22, 0.23, and 0.24 mg/L. At well 150-MW04S,

TABLE 5.5 Summary of Sampling Rounds and Analyses[a]

Sampling Round	Sampling Location									
	150-MW01S	150-MW01D	150-MW02	150-MW03	150-MW04S	150-MW04D	150-MW05S	150-MW05D	150-MW06S	150-MW06D
1	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	Total metals	Total metals	Total metals	Total metals
2	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	VOC, SVOC, pest/PCB, total metals, radio-activity, misc. parameters	Total metals	Total metals	Total metals	Total metals
3	Total metals	Total metals	Total metals	Total metals	Total metals	Total metals	Not collected	Not collected	Not collected	Not collected
4	Total metals	Total metals	Total metals	Total metals	Total metals	Total metals	Not collected	Not collected	Not collected	Not collected
5	Total, dissolved metals	Total, dissolved metals	Not collected	Not collected	Total, dissolved metals	Total, dissolved metals	Not collected	Not collected	Not collected	Not collected

[a] In a given round, groundwater samples were not collected from a given monitoring well, as indicated, if earlier groundwater sampling results did not show any exceedences of background values or SROs.

TABLE 5.6 Total Metals Concentrations in Groundwater[a,b]

Sampling Location	150-MW01S-01	150-MW01S-02	150-MW01S-03	150-MW01S-04	150-MW01S-05	GRO[c]
Date Collected	2/22/00	4/6/00	8/30/00	10/16/00	2/8/01	
Aluminum	NA	0.2U	0.011B	0.02B	0.026	-
Antimony	0.02U	0.02U	0.0031U	0.0031U	0.0016U	0.006
Arsenic	0.01U	0.01U	0.0014U	0.0014U	0.0024U	0.05
Barium	0.1U	0.1U	0.062B	0.063	0.054	2
Beryllium	0.005U	0.005U	0.00013U	0.00013U	0.00032	0.004
Cadmium	0.005U	0.005U	0.00022U	0.00022U	0.00033	0.005
Calcium	NA	160	130	150	150	-
Chromium	NA	0.01U	0.0014B	0.00083	0.0014	0.1
Cobalt	0.01U	0.01U	0.00057U	0.0078	0.0016	1
Copper	0.01U	0.01U	0.0021B	0.0012	0.0029	0.65
Iron	NA	0.57	0.49	1.4	0.99	5
Magnesium	NA	59	50	55	59	-
Manganese	NA	0.01U	0.024	**0.21**	0.025	0.15
Nickel	0.02U	0.02U	0.044	**0.37**	0.035	0.1
Potassium	NA	5.1	6.5	5.3	3.2	-
Selenium	0.005U	0.0074	0.0038U	0.0044	0.0023U	0.05
Silver	0.01U	0.01U	0.00054U	0.00054U	0.0005	0.05
Sodium	NA	41	31	31	31	-
Thallium	0.01U	0.01U	0.0037U	**0.0042**	0.0028U	0.002
Vanadium	0.01U	0.01U	0.00052	0.00032U	0.00047U	0.049
Zinc	0.02U	0.02U	0.011B	0.005	0.021	5

Sampling Location	150-MW01D-01	150-MW01D-02	150-MW01D-03	150-MW01D-DUP	150-MW01D-04	150-MW01D-05	GRO[c]
Date Collected	2/22/00	4/6/00	8/30/00	10/20/00	10/23/00	1/18/01	
Aluminum	NA	0.2U	0.0075U	0.0075U	0.0075U	0.016U	-
Antimony	0.02U	0.02U	0.0031U	0.0031U	0.0031U	0.0016U	0.006
Arsenic	0.01U	0.01U	0.0034B	0.0014U	0.0014U	0.0024U	0.05
Barium	0.1U	0.1U	0.061	0.055	0.057	0.061	2
Beryllium	0.005U	0.005U	0.00013U	0.00013U	0.00013U	0.00053	0.004
Cadmium	0.005U	0.005U	0.00022U	0.00022U	0.00022U	0.00028	0.005
Calcium	NA	190	190	190	190	200	-
Chromium	0.049	0.024	0.034	0.032	0.044	0.053	0.1
Cobalt	0.01U	0.01U	0.0035B	0.0044B	0.0063	0.0035	1
Copper	0.018	0.01U	0.0057B	0.0042B	0.0053	0.0033	0.65
Iron	NA	0.61	1.1	0.5	0.6	1.2	5
Magnesium	NA	97	100	99	99	100	-
Manganese	NA	0.14	0.096	0.092	0.1	0.077	0.15
Nickel	**0.12**	**0.24**	0.077	**0.23**	**0.3**	0.1	0.1
Potassium	NA	5.9	5.1	5.1	5.1	5.7	-
Selenium	0.005U	0.005U	0.0038U	0.0038U	0.0038U	0.0023	0.05
Silver	0.01U	0.01U	0.00054U	0.00054U	0.00054U	0.00035	0.05
Sodium	NA	92	89	90	91	90	-
Thallium	0.01U	0.01U	0.0037U	0.0037U	0.0037U	0.0038	0.002
Vanadium	0.01U	0.01U	0.00042	0.00032U	0.00032U	0.00086	0.049
Zinc	0.02U	0.02U	0.017	0.0086	0.013	0.021	5

TABLE 5.6 (Cont.)

Sampling Location	150-MW02-01	150-MW02-02	150-MW02-03	150-MW02-04	GRO[c]
Date Collected	2/23/00	3/28/00	9/1/00	10/17/00	
Aluminum	NA	NA	0.0075U	0.088B	-
Antimony	0.02U	0.02U	0.0031U	0.0031U	0.006
Arsenic	0.01U	0.01U	0.0066B	0.0071B	0.05
Barium	0.1U	0.1U	0.045B	0.047	2
Cadmium	0.005U	0.005U	0.00022U	0.00022U	0.005
Calcium	NA	NA	170	180	-
Chromium	0.01U	0.01U	0.016	0.011	0.1
Cobalt	0.01U	0.01U	0.0021	0.0015	1
Copper	0.01U	0.01U	0.0025	0.0012	0.65
Iron	NA	NA	2.3	2.4	5
Magnesium	NA	NA	90	93	-
Manganese	NA	NA	0.12	0.096	0.15
Nickel	0.02U	0.02U	0.015	0.012	0.1
Potassium	NA	NA	3.7	3.6	-
Selenium	0.005U	0.005U	0.0038U	0.0038U	0.05
Silver	0.01U	0.01U	0.00054U	0.00054U	0.05
Sodium	NA	NA	170	170	-
Thallium	0.01U	0.01U	0.0037U	0.0037U	0.002
Vanadium	0.01U	0.01U	0.00081	0.00032U	0.049
Zinc	0.02U	0.02U	0.0061	0.0077	5

Sampling Location	150-MW03-01	150-MW03-02	150-MW03-DUP	150-MW03-03	150-MW03-04	GRO[c]
Date Collected	2/24/00	3/28/00	9/1/00	9/1/00	10/17/00	
Aluminum	NA	NA	0.0075U	0.0075U	0.013	-
Antimony	0.02U	0.02U	0.0031U	0.0031U	0.0031U	0.006
Arsenic	0.01U	0.01U	0.011	0.0099B	0.013	0.05
Barium	0.1U	0.1U	0.06	0.061	0.062	2
Beryllium	0.005U	0.005U	0.00013U	0.0013U	0.00013U	0.004
Cadmium	0.005U	0.005U	0.00022U	0.00022U	0.00022U	0.005
Calcium	NA	NA	190	190	200	-
Chromium	0.01U	0.01U	0.041	0.046	0.08	0.1
Cobalt	0.01U	0.01U	0.0011	0.0018	0.002	1
Copper	0.01U	0.01U	0.003	0.0048B	0.001	0.65
Iron	NA	NA	2.5	2.5	2.5	5
Magnesium	NA	NA	100	100	100	-
Manganese	NA	NA	0.22	0.23	0.24	0.15
Nickel	0.02U	0.02U	0.035	0.052	0.052	0.1
Potassium	NA	NA	3.8	3.8	3.8	-
Selenium	0.005U	0.005U	0.0038U	0.0038U	0.0038U	0.05
Silver	0.01U	0.01U	0.00054U	0.00054U	0.00054U	0.05
Sodium	NA	NA	170	170	170	-
Thallium	0.01U	0.01U	0.0037U	0.0037U	0.0037U	0.002
Vanadium	0.01U	0.01U	0.00032U	0.00032U	0.00032U	0.049
Zinc	0.02U	0.02U	0.02	0.013	0.013	5

TABLE 5.6 (Cont.)

Sampling Location	150-MW04S-01	150-MW04S-02	150-MW04S-03	150-MW04S-04	150-MW04S-05	GRO[c]
Date Collected	2/24/00	3/29/00	9/1/00	10/19/00	2/9/01	
Aluminum	NA	0.2U	0.0075U	0.024B	0.017	-
Antimony	0.02U	0.02U	0.0031U	0.0031U	0.0016U	0.006
Arsenic	0.01U	0.01U	0.0014U	0.0014U	0.0048	0.05
Barium	0.1U	0.1U	0.036	0.038	0.026	2
Beryllium	0.005U	0.005U	0.00013U	0.00013U	0.0004	0.004
Cadmium	0.005U	0.005U	0.00022U	0.00022U	0.00013U	0.005
Calcium	NA	140	140	150	150	-
Chromium	0.041	0.051	0.92	1.3	1.6	0.1
Cobalt	0.01U	0.01U	0.019	0.024	0.054	1
Copper	0.032	0.01U	0.0073	0.0047	0.0066	0.65
Iron	NA	2.1	**14**	**17**	**44**	5
Magnesium	NA	71	64	68	63	-
Manganese	NA	0.23	0.47	0.57	1.1	0.15
Nickel	0.3	0.45	1.9	2.4	5.7	0.1
Potassium	NA	3.1	2.6	2.7	2.4	-
Selenium	0.005U	0.005U	0.0058	0.0038U	0.0023U	0.05
Silver	0.01U	0.01U	0.00054U	0.00054U	0.00035U	0.05
Sodium	NA	110	69	88	51	-
Thallium	0.01U	0.01U	0.0037U	0.00037U	0.0028U	0.002
Vanadium	0.01U	0.01U	0.0053	0.0072	0.0085	0.049
Zinc	0.02U	0.02U	0.0093	0.0053	0.025	5

Sampling Location	150-MW04D-01	150-MW04D-02	150-MW04D-03	150-MW04D-04	150-MW04D-05	GRO[c]
Date Collected	2/23/00	3/29/00	9/1/00	10/19/00	2/9/01	
Aluminum	NA	0.2U	0.0075U	0.022	0.041	-
Antimony	0.02U	0.02U	0.0031U	0.0031U	0.0016U	0.006
Arsenic	0.01U	0.01U	0.0093B	0.0057	0.0077	0.05
Barium	0.1U	0.1U	0.056	0.054	0.059	2
Beryllium	0.005U	0.005U	0.00013U	0.00013U	0.00041	0.004
Cadmium	0.005U	0.005U	0.00022U	0.00022U	0.0002	0.005
Calcium	NA	180	180	190	190	-
Chromium	0.032	0.032	0.016	0.03	0.018	0.01
Cobalt	0.01U	0.01U	0.00072	0.0011	0.0016	1
Copper	0.01U	0.01U	0.00069	0.0012	0.00072U	5
Iron	NA	1.2	3.2	2.2	3.1	-
Magnesium	NA	100	100	100	110	-
Manganese	NA	0.094	0.047	0.052	0.038	0.15
Nickel	0.23	0.19	0.058	0.062	0.057	0.1
Potassium	NA	4.5	0.0038U	4.4	5.1	-
Selenium	0.005U	0.005U	0.0038U	0.0038U	0.0023U	0.05
Sodium	NA	71	63	67	67	-
Thallium	0.01U	0.01U	0.0037U	0.0037U	0.00051	0.002
Vanadium	0.01U	0.01U	0.00032U	0.00037	0.049	0.049
Zinc	0.02U	0.02U	0.0055	0.0051	0.16	5

TABLE 5.6 (Cont.)

Sampling Location	150-MW05S-01	150-MW05S-02	GRO[c]
Date Collected	8/30/00	10/19/00	
Aluminum	0.0075U	0.19B	-
Antimony	0.0031U	0.0031U	0.006
Arsenic	0.0014U	0.0014U	0.05
Barium	0.053B	0.055B	2
Beryllium	0.00013U	0.00013U	0.004
Cadmium	0.00022U	0.00022U	0.005
Calcium	150	160	-
Chromium	0.00035U	0.00052B	0.1
Cobalt	0.0018B	0.002B	1
Copper	0.0005B	0.0011B	0.65
Iron	0.42	0.79	5
Magnesium	80	84	-
Manganese	0.49	0.47	0.15
Nickel	0.0054B	0.0085B	0.1
Potassium	3.9	4.2	-
Selenium	0.0038U	0.0038U	0.05
Sodium	130	140	-
Thallium	0.0037U	0.0037U	0.002
Vanadium	0.00032U	0.00032U	0.049
Zinc	0.0032U	0.0036B	5

Sampling Location	150-MW05D-01	GRO[c]	150-MW06S-01	150-MW06S-02	GRO[c]
Date Collected	10/20/00		8/30/00	10/20/00	
Aluminum	0.014B	-	0.0075U	0.067B	-
Antimony	0.0031U	0.006	0.0031U	0.02U	0.006
Arsenic	0.0014U	0.05	0.0014U	0.0014U	0.05
Barium	0.069	2	0.045	0.049B	2
Beryllium	0.00031U	0.004	0.00013U	0.00013U	0.004
Cadmium	0.00022U	0.005	0.00022U	0.00022U	0.005
Calcium	200	-	120	140	-
Chromium	0.003	0.1	0.00035U	0.00035U	0.1
Cobalt	0.0013	1	0.0017B	0.0015B	1
Copper	0.0021	0.65	0.00071B	0.00097B	0.65
Iron	0.12	5	0.08B	0.19	5
Magnesium	98	-	49	55	-
Manganese	0.098	0.15	0.21	0.13	0.15
Nickel	0.074	0.1	0.0061B	0.0068B	0.1
Potassium	7.7	-	2	2.3	-
Selenium	0.0038U	0.05	0.0038U	0.00038U	0.05
Sodium	88	-	36	42	-
Thallium	0.0037U	0.002	0.0037U	0.0037U	0.002
Vanadium	0.00032U	0.049	0.00052	0.00032U	0.049
Zinc	0.02	5	0.0032U	0.00032U	5

[a] Concentrations are in mg/L.

[b] A hyphen indicates that no GRO exists for this metal. Bold indicates that the level exceeds the GRO. B = estimated; value shown is less than the PQLs but greater than or equal to the MDLs. U = undetected; value shown is the detection limit.

[c] GRO derived from Table E, Appendix B, IEPA TACO Guidance (35 IAC 742), Class I Groundwater.

TABLE 5.7 Dissolved Metals Concentrations in Groundwater[a,b]

Sample Location	150-MW01S-05	150-MW01D-05	150-MW04S-05	150-MW04D-05	GRO[c]
Date Collected	2/8/01	1/18/01	2/9/01	2/9/01	
Aluminum	0.016U	0.016U	0.029	0.016U	-
Antimony	0.0016U	0.0016U	0.0016U	0.0018	0.006
Arsenic	0.0024U	0.0024U	0.0024U	0.0063	0.05
Barium	0.052	0.06	0.025	0.058	2
Beryllium	0.00037	0.00056	0.00029	0.0005	0.004
Cadmium	0.00035	0.00027	0.0002	0.00032	0.005
Calcium	150	200	150	190	-
Chromium	0.0011	0.00055	0.028	0.00081	0.1
Cobalt	0.0014	0.00038	0.038	0.0012	1
Copper	0.0036	0.0017	0.0011	0.00072U	0.65
Iron	0.1	0.51	**27**	2.5	5
Magnesium	59	100	63	100	-
Manganese	0.016	0.081	**0.78**	0.035	0.15
Nickel	0.023	**0.13**	**3.8**	0.054	0.1
Potassium	3.2	5.7	2.3	5	-
Silver	0.00035U	0.00035U	0.00035U	0.00056	0.05
Sodium	33	89	50	66	-
Thallium	0.0028U	0.0028U	0.0028U	0.00029	0.002
Vanadium	0.00047U	0.00047U	0.0011	0.00047U	0.049
Zinc	0.014	0.04	0.021	0.01	5

[a] Concentrations are in mg/kg.

[b] A hyphen indicates that no GRO exists for this metal. Bold indicates that the level exceeds the GRO. U = undetected; value shown is the detection limit.

[c] GRO derived from Table E, Appendix B, IEPA TACO Guidance (35 IAC 742), Class I Groundwater.

manganese was detected above its GRO in the second, third, fourth, and fifth rounds of groundwater sampling, at concentrations of 0.23, 0.47, 0.57, and 1.1 mg/L, respectively. At well 150-MW05S, manganese was detected above its GRO in both rounds of groundwater sampling, at concentrations of 0.49 and 0.47 mg/L. At well 150-MW06S, manganese was detected above its GRO in the first round of groundwater sampling at a concentration of 0.21 mg/L.

Prior ANL experience with groundwater sampling across the ANL-E site indicates that wells screened in the glacial till often produce turbid samples because of the presence of clay soil fines in the samples. Historical results from analysis of filtered groundwater samples from glacial till wells across the ANL-E site, as well as in wells several miles from the ANL-E site (ANL 2000b), show that although the amounts of solids and metals detected are lower than those in unfiltered samples, the metals concentrations have not been eliminated. As discussed in Section 3.5, ANL-E collected unfiltered groundwater samples at SWMU No. 150 by using a low-flow sampling system consisting of a bladder pump powered by compressed air. Samples were collected under static hydraulic head at steady-state flow rates as low as 40 mL/min. While this collection method limited the amount of suspended soil particles, it was not able to eliminate all particles.

While the presence of manganese, as well as iron and thallium, in the groundwater at concentrations above their GROs may seem to imply that soils in the area contain these metals at concentrations above their respective migration-to-groundwater values for the specific pH range found in the soil, ANL believes that this is not the case in the vicinity of SWMU No. 150. The metals detected in and near SWMU No. 150 are not indicative of a release of manganese from this unit but are consistent with area background levels of manganese. In fact, manganese has been detected at concentrations above its GRO in numerous wells across the ANL-E site, as well as in wells several miles from the ANL-E site (ANL 2000b). This finding suggests that the elevated manganese levels in groundwater likely came from soil solids present in the unfiltered sample, even at extremely low turbidity values. It does not appear that manganese has been released to the groundwater.

Nickel was detected at a concentration above its GRO of 0.1 mg/L in groundwater samples collected at four well locations. At well 150-MW01S, nickel was detected in the fourth round of sampling at a concentration of 0.37 mg/L. At well 150-MW01D, nickel was detected in the second, third, and fourth rounds of sampling at concentrations of 0.24, 0.23, and 0.3 mg/L, respectively. At well 150-MW04S, nickel was detected in samples from all five rounds of groundwater sampling at concentrations of 0.3, 0.45, 1.9, 2.4, and 5.7 mg/L. At well 150-MW04D, nickel was detected in the first and second rounds of sampling at concentrations of 0.23 and 0.19 mg/L.

Chromium was detected above its GRO of 0.1 mg/L at one well location. At well 150-MW04S, chromium was found in groundwater samples in the third, fourth, and fifth rounds of sampling at concentrations of 0.92, 1.3, and 1.6 mg/L.

Thallium was detected above its GRO of 0.002 mg/L at one well location. At well 150-MW01S, thallium was found in the groundwater samples collected in the fourth round of sampling at a concentration of 0.0042 mg/L.

5.2.1.2 Dissolved (Filtered) Metals

Iron was detected above its GRO of 5 mg/L at one well location. At well 150-MW04S, iron was found in the groundwater samples collected in the third, fourth, and fifth rounds of sampling at concentrations of 14, 17, and 44 mg/L, respectively.

During the fifth round of groundwater sampling at wells 150-MW01S/D and 150-MW04S/D, groundwater was also collected for dissolved metals analysis. Because of the continued presence of elevated (above the GRO) nickel concentrations at wells 150-MW04S/D, and 150-MW01S/D, and chromium concentrations at well 150-MW04S, ANL decided to collected both filtered and unfiltered samples from these wells. The purpose of the filtered samples was to determine whether the elevated concentrations of these metals resulted from suspended soil particles in the sample or whether they actually represented dissolved metals in the groundwater. These two well clusters were selected because they were the only wells in which groundwater sample results indicated metals concentrations exceeding Tier 1 GROs.

Nickel, iron, and manganese were the only metals present in the dissolved groundwater sample at concentrations above their respective GROs. At well 150-MW01D, nickel was present in the filtered groundwater sample at a concentration of 0.13 mg/L, which is just above the GRO of 0.1 mg/L. At well 150-MW04S, nickel was present in the filtered groundwater at a concentration of 3.8 mg/L (compared to a GRO of 0.1 mg/L), iron was present at a concentration of 27 mg/L (compared to a GRO of 5 mg/L), and manganese was present at a concentration of 0.78 mg/L (compared to a GRO of 0.15 mg/L). At the other wells previously showing elevated metals concentrations in the unfiltered samples (150-MW01S and 150-MW04D), all metals in the filtered sample were found to be below their GROs.

5.2.2 VOCs

Data on the detectable levels of VOCs are presented in Table 5.8. A total of five VOCs were detected in the groundwater samples; however, all concentrations were estimated and were well below their respective GROs.

TABLE 5.8 VOC Concentrations in Groundwater[a,b]

Sample Location	150-MW01S-01	150-MW01S-02	150-MW01D-02	150-MW02-01	GRO[c]
Acetone	14J	12JB	20U	20U	700
1,1-Dichloroethane	0.8J	1.3J	5U	5U	700
Methylene chloride	5U	5U	2.4JB	5U	5
Toluene	5U	5U	5U	0.61J	1000

Sample Location	150-MW03-01	150-MW04S-01	150-MW04S-02		GRO[c]
Acetone	20U	20U	20U		700
1,1-Dichloroethane	5U	1.1J	4.6J		700
1,1,1-trichloroethane	5U	2J	3.6J		200
Methylene chloride	5U	5U	5U		5
Toluene	0.61J	5U	5U		1000

[a] Concentrations are in µg/L.

[b] B = compound also found in associated laboratory blank. J = estimated value, below detection limit. U = undetected; value shown is the detection limit.

[c] GRO derived from Table E, Appendix B, IEPA TACO Guidance (35 IAC 742), Class I Groundwater.

5.2.3 SVOCs

Only two SVOCs were detected in the groundwater samples. Bis(2-ethylhexyl)phthalate was detected at estimated concentrations across the first two rounds of sampling in monitoring wells 150-MW01S/D, 150-MW02, 150-MW03, and 150-MW04S/D. This compound is a common laboratory contaminant; its presence in these samples at these low concentrations can be attributed to laboratory contamination. 2,4-Dimethylphenol was detected at estimated concentrations in the first round of sampling at monitoring wells 150-MW01D, 150-MW02, and 150-MW04D. However, this compound was also present in the laboratory method blank, and its presence in these samples therefore can be attributed to laboratory contamination. Both compounds were detected at concentrations well below their respective GROs.

5.2.4 Pesticides/PCBs

No pesticides or PCBs were detected in the groundwater samples.

5.2.5 Miscellaneous Parameters

Concentrations of miscellaneous parameters are listed in Table 5.9. Chloride was the only miscellaneous parameter that exceeded its GRO. At well 150-MW02-02, chloride was detected at a maximum concentration of 600 mg/L, compared to a GRO of 462.3 mg/L. All other miscellaneous parameters were below their GROs.

TABLE 5.9 Miscellaneous Parameters Concentrations in the Groundwater[a,b]

Sample Location	150-MW01S-01	150-MW01S-02	150-MW01D-01	150-MW01D-02	GRO[c]
Chloride	NC	NC	410	NC	462.3[d]
Sulfate	NC	NC	170	NC	400[e]
Total organic carbon	NC	5.2	1.2	3	55.4[d]
Total organic halides (µg/L)	NC	19	31	18	144.1[d]
Sample Location	150-MW02-01	150-MW02-02	150-MW03-01	150-MW03-02	
Chloride	**510**	NC	**600**	NC	462.3[d]
Sulfate	180	NC	200	NC	400[e]
Total organic carbon	3.5	3.5	2.7	3.8	55.4[d]
Total organic halides (µg/L)	25	25	49	24	144.1[d]
Sample Location	150-MW04S-01	150-MW04S-02	150-MW04D-01	150-MW04D-02	
Chloride	320	260	410	400	462.3[d]
Sulfate	230	210	150	150	400[e]
Total organic carbon	3.8	2.2	3.9	2.3	55.4[d]
Total organic halides (µg/L)	25	25	10U	37	144.1[d]

[a] Concentrations are in mg/L unless otherwise indicated.

[b] NC = sample volume not collected due to insufficient monitoring well production. U = undetected, value shown is the detection limit. Bold indicates that the level exceeds the GRO.

[c] GRO is either the TACO Tier 1 value or the ANL-E sitewide 95% UTL.

[d] ANL-E sitewide 95% UTL.

[e] GRO derived from Table E, Appendix B, IEPA TACO Guidance (35 IAC 742), Class I Groundwater.

5.2.6 Radionuclides

Radionuclide data for the groundwater samples are provided in Table 5.10. Gross alpha levels exceeded background levels in the upgradient well. Detectable levels of the uranium isotopes (U-234, U-235, and U-238) were found to be present in both rounds of sampling in wells 150-MW01S/D, 150-MW02, 150-MW03, and 150-MW04S/D. At wells 150-MW02 and 150-MW03, the levels were consistent with ambient ANL-E levels. However, at wells 150-MW01S/D and 150-MW04S, these isotopes were present at levels above those normally considered to be ambient ANL-E levels. The elevated gross alpha activity at these wells probably can be attributed to the elevated levels of uranium isotopes in the groundwater. Strontium-90 was the only man-made radioisotope detected. At well 150-MW01S, strontium-90 was detected in both rounds of groundwater sampling at concentrations of 0.53 and 0.68 pCi/L, respectively. Tritium was not detected in any of the groundwater samples.

TABLE 5.10 Radionuclide Concentrations in Groundwater[a,b]

Sample Location	150-MW01S-01	150-MW01S-02	150-MW01D-01	150-MW01D-02	
Date Collected	2/22/00	4/6/00	2/22/00	4/6/00	
Gross Alpha	**34.2+/-5.9**	**38.8+/-6.2**	**15.7+/-3.9**	6.2+/-3.4	
Gross Beta	**9.1+/-2.6**	**26.8+/-4.3**	**9.9+/-4.2**	**11.1+/-4.5**	
Sr-90	0.53+/-0.27	0.68+/-0.33	<0.40U	<0.48U	
Isotopic Uranium					
U-234	**15+/-2.2**	**14.7+/-2**	**2.76+/-0.63**	1.76+/-0.29	
U-235	**1.6+/-0.24**	**0.95+/-0.18**	**0.23+/-0.20**	0.122+/-0.050	
U-238	**20+/-2.9**	**19.9+/-2.7**	2.17+/- 0.54	1.53+/-0.26	
Sample Location	150-MW02-01	150-MW02-02	150-MW03-01	150-MW03-02	
Date Collected	2/23/00	3/28/00	2/24/00	3/28/00	
Gross Alpha	<6.2U	8.1+/-3.9	<6.4U	7.7+/-3.5	
Gross Beta	5.4+/-3.5	5.5+/-3.6	<5.7U	**17.6+/-4.8**	
Sr-90	<0.41U	<0.34U	<0.38U	<0.38U	
Isotopic Uranium					
U-234	2.54+/-0.41	2.29+/-0.37	1.41+/-0.25	1.50+/-0.27	
U-235	0.113+/-0.051	0.136+/-0.055	0.113+/-0.050	**0.143+/-0.059**	
U-238	2.30+/-0.37	1.82+/-0.31	1.23+/-0.22	1.34+/-0.24	
Sample Location	150-MW04S-01	150-MW04S-02	150-MW04D-01	150-MW04D-02	
Data Collected	2/24/2000	3/29/2000	2/23/2000	3/29/2000	Background[c]
Gross Alpha	**13.9+/-3.7**	**9.4+/-2.6**	2.3+/-1.7	<3.2U	8.1+/-3.9
Gross Beta	**6.5+/-2.8**	**4.4+/-2.4**	4.4+/-2.1	4.1+/-2.6	5.5+/-3.6
Sr-90	<0.39U	<0.34U	<0.44U	<0.30U	-
Isotopic Uranium					
U-234	**4.60+/-0.67**	**3.56+/-0.54**	0.59+/-0.13	0.360+/-0.095	2.54+/-0.41
U-235	**0.236+/-0.072**	**0.298+/-0.086**	0.051+/-0.032	<0.046U	0.136+/-0.055
U-238	**4.86+/-0.71**	**5.17+/-0.76**	0.48+/-0.11	0.313+/-0.087	2.30+/-0.37

[a] Concentrations are in pCi/L.

[b] U = undetected; value shown is the detection limit. Bold indicates that the level exceeds the background value.

[c] Background values derived from maximum result of background monitoring well sampling.

The uranium isotopes present in the groundwater samples can be addressed by using standards developed for the remediation of uranium and thorium mill tailing sites, as contained in 40 CFR 192, Subpart A, entitled "*Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites*" (EPA 2000). More specifically, Section 192.02 of Subpart A states that concentrations of listed constituents (in this case, uranium-234 and uranium-238) in groundwater must not exceed either (1) the background level of the constituent in the groundwater, or (2) the maximum concentration of the constituent as listed in Table 1 to Subpart A, if the background value is less that the value listed in Table 1. This value is 30 pCi/L for the uranium-234 and uranium-238 added together.

At SWMU No. 150, the ingestion exposure pathway assumes that a future resident of the site will receive a chronic dose of uranium by being exposed to the uranium-containing groundwater every day. Comparing the background value or the standard in 40 CFR 192.02 to the maximum concentration would skew the comparison toward an overly conservative conclusion because it is unlikely that a resident of the site would drink water from a well containing the maximum uranium isotope concentrations over a lifetime. Therefore, the averaged result of all groundwater samples collected in the vicinity of SWMU No. 150 would represent the average exposure concentration for the groundwater body underneath SWMU No. 150 better than a sample from an individual well. The average value was calculated and compared to both the background value for combined uranium-234 and uranium-238 as well as the value listed in 40 CFR 192, Subpart A, Table 1.

Table 5.11 presents the uranium isotope data collected from the monitoring wells installed in the vicinity of SWMU No. 150. The average concentration for the combined uranium-234 and uranium-238 is compared to both the background value derived for this SWMU as well as the value listed in Table 1 of 40 CFR 192, Subpart A. For uranium isotopes, the analytical results for the groundwater samples indicated combined uranium concentrations ranging from 2.64 to 35 pCi/L. The resulting average concentration, which was derived from a total of 12 groundwater samples, was 9.33 pCi/L. This value, which is representative of groundwater conditions underneath SWMU No. 150, is above the background value of 4.84 pCi/L, which is the maximum result from the SWMU No. 150 background well. However, it is well below the allowable amount for groundwater protection of 30 pCi/L for combined uranium-234 and uranium-238, as presented in 40 CFR 192, Subpart A, Table 1. Thus, the existing levels of uranium isotopes at SWMU No. 150 are low enough that they do not require remedial actions.

TABLE 5.11 Comparison of Average Concentrations of Isotopic Uranium with Local Background and Groundwater Standards for Remedial Actions at Inactive Uranium Processing Sites[a,b]

Sampling Location	150-MW01S-01	150-MW01S-02	150-MW01D-01	150-MW01D-02
Date Collected	2/22/00	4/6/00	2/22/00	4/6/00
U-234	15	14.7	2.76	1.76
U-238	20	19.9	2.17	1.53
Combined Total	35	34.6	4.93	3.29
	Background Value[c]			
Sampling Location	150-MW02-01	150-MW02-02	150-MW03-01	150-MW03-02
Date Collected	2/23/00	3/28/00	2/24/00	3/28/00
U-234	2.54	2.29	1.41	1.5
U-238	2.3	1.82	1.23	1.34
Combined Total	4.84	4.11	2.64	2.84
Sampling Location	150-MW04S-01	150-MW04S-02	150-MW04D-01	150-MW04D-02
Date Collected	2/24/00	3/29/00	2/23/00	3/29/00
U-234	4.6	3.56	0.59	0.36
U-238	4.86	5.17	0.48	0.313
Combined Total	9.46	8.73	1.07	0.673
AVERAGE VALUE	**9.33**			
Background Value (pCi/L)	**4.84**			
40 CFR 192.02, Table 1 (pCi/L)	**30**			

[a] Concentrations in pCi/L.

[b] Source: EPA 2000.

[c] Background value is taken to be the higher of the two samples from the upgradient well.

6 CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the significant findings of the soil and groundwater investigation program at SWMU No. 150. These findings are discussed in detail in Chapters 4 and 5.

6.1 GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology were characterized through a series of soil borings and groundwater monitoring wells installed in and around the former Building 34 – Liquid Mixed Waste Treatment area. Soil boring data indicate that groundwater is present in two distinct porous zones. The shallower zone, located at about 656 ft amsl, is present in all the "S" wells and the wells with no alphabetical designation. Groundwater elevation data from this shallower zone indicate a very slight westward groundwater gradient, toward Sawmill Creek. Insufficient groundwater elevation data were available to determine groundwater flow direction for the deeper zone.

6.2 SUBSURFACE SOILS

In the subsurface soils, a total of 14 VOCs were detected in the subsurface soil samples, but all concentrations were found to be below their respective SROs. Four SVOCs were present at estimated concentrations in the subsurface soil samples, but their concentrations were also below their SROs. Two pesticides and one PCB were detected in the subsurface soils, but at concentrations well below their SROs. Results of radioactivity analysis of the subsurface soil samples indicate that the levels of gross alpha, gross beta, and uranium isotopes exceed the background values for these radionuclides in several subsurface soil samples.

Three metals — arsenic, tin, and thallium — were detected in subsurface soil samples at levels just above their respective SROs. These maximum results were compared to results for these metals averaged from the eight initial soil borings drilled in and around SWMU No. 150. For each metal, the averaged result over the SWMU No. 150 area was well below the SRO for the metal. The soil does not appear to be contaminated above SROs, and thus, no remedial actions are warranted.

6.3 GROUNDWATER

In the groundwater, data from up to five rounds of sampling showed that five metals — manganese, chromium, nickel, iron, and thallium — were present in the unfiltered groundwater at concentrations above their GROs. Manganese was present above its GRO in five shallow wells at SWMU No. 150, including one of the background groundwater monitoring wells. However, the manganese levels detected are consistent with levels of manganese found in wells across the ANL-E site, as well as wells up to several miles offsite (ANL 2000b). Manganese, iron, and thallium present in groundwater samples at SWMU No. 150 are therefore probably the result of suspended soil particles in the samples and do not represent a release from the unit.

Chromium was present at concentrations above its GRO at one well location. At well 150-MW04S, located about 8 ft downgradient of both the former acid and metals tanks, chromium was found in groundwater samples above its GRO of 0.1 mg/L in the third, fourth, and fifth rounds of sampling, at concentrations of 0.92, 1.3, and 1.6 mg/L.

Nickel was present above its GRO of 0.1 mg/L at four well locations. At well 150-MW01S, nickel was detected in the groundwater at a maximum concentration of 0.37 mg/L. At well 150-MW01D, nickel was detected in the groundwater at a maximum concentration of 0.3 mg/L. At well 150-MW04S, nickel was detected in the groundwater at a maximum concentration of 5.7 mg/L. In fact, concentrations of nickel in the unfiltered groundwater samples collected from well 150-MW04S increased across all five sampling points, with the maximum result reported in the final round of sampling. At well 150-MW04D, nickel was detected in the groundwater at a maximum concentration of 0.23 mg/L.

Comparison of these results with the results of filtered groundwater samples collected at the same time during the fifth round of sampling show lower metals concentrations in the filtered samples. At well 150-MW04S, iron, manganese, and nickel were present in the filtered (dissolved) sample at levels above their GROs, at concentrations of 27, 0.78, and 3.8 mg/kg, respectively. Nickel was also present in the filtered sample at well 150-MW01D, at a concentration of 0.13 mg/kg, as compared to the GRO of 0.1 mg/kg. The presence of iron, manganese, and nickel at well 150-MW04S at concentrations above their GROs in the filtered sample suggests a significant dissolved component of these metals to the filtered sample from shallow groundwater. The lower level of nickel in well 150-MW01D, as compared to the unfiltered sample, while still slightly above the GRO, suggests that nickel is present primarily in suspended solids in the deeper groundwater.

6.4 RECOMMENDATIONS

On the basis of the elevated levels of nickel (up to 5.7 mg/L) in one monitoring well, as well as lower (but still in excess of Tier 1 values) concentrations of chromium and manganese in wells immediately west and north of the former Building 34, it appears that the groundwater may have been impacted by operations at the former Building 34. Contamination generally appears to be restricted to the shallow water-bearing zone adjacent to the former Building 34. Much lower levels of metals contamination in the deeper wells at these locations (150-MW01D and 150-MW04D) are not consistently present across the various sampling rounds and probably represent the presence of suspended soil particles in the groundwater samples. ANL believes that releases of liquid waste from the in-ground concrete liquid waste treatment tanks along the west and north sides of the building entered the clay soils under the tanks and possibly the shallow water-bearing zone. The relatively high levels of metals contamination in wells adjacent to these tanks contrasts with very low levels (in some cases undetectable levels) of the same metals in both downgradient and upgradient monitoring wells. This finding suggests that contamination is a localized problem, in the immediate vicinity of the former concrete tanks, resulting from leaking wastewater from the tanks that caused the soil pore water to become contaminated. Figure 6.1 is an isoconcentration map showing the distribution of nickel contamination in the shallow groundwater. Nickel was used to illustrate the extent of shallow metals groundwater contamination because of its presence in all sampling rounds at well 150-MW04S, as well as at well 150-MW01S. It should be noted that the accuracy of the contours increases toward well 150-MW04S and uncertainty increases toward the north. This is caused by the lack of monitoring wells north and west of well 150-MW01S. However, because nickel was present west of SWMU No. 150 at levels below its GRO (well 150-MW05S) and present just above its GRO north of the SWMU (at well 150-MW01S), it is unlikely that the contaminated groundwater extends beyond well 150-MW01S.

ANL proposes therefore to excavate soils in and around the contaminated shallow water-bearing zone along the west and northwest sides of the former Building 34. This action should effectively remove the reservoir of contaminated pore water present in soils near and within the water-bearing zone. A construction work plan (CWP) addressing the removal of these soils is contained in Appendix F of this investigation report. The CWP describes the approach and rationales regarding excavation of soils near and within the contaminated water-bearing zone, and details field procedures for excavation and disposal of contaminated soils. A construction report describing the remediation effort will be prepared and submitted to the IEPA, and will include an NFA request for this SWMU.

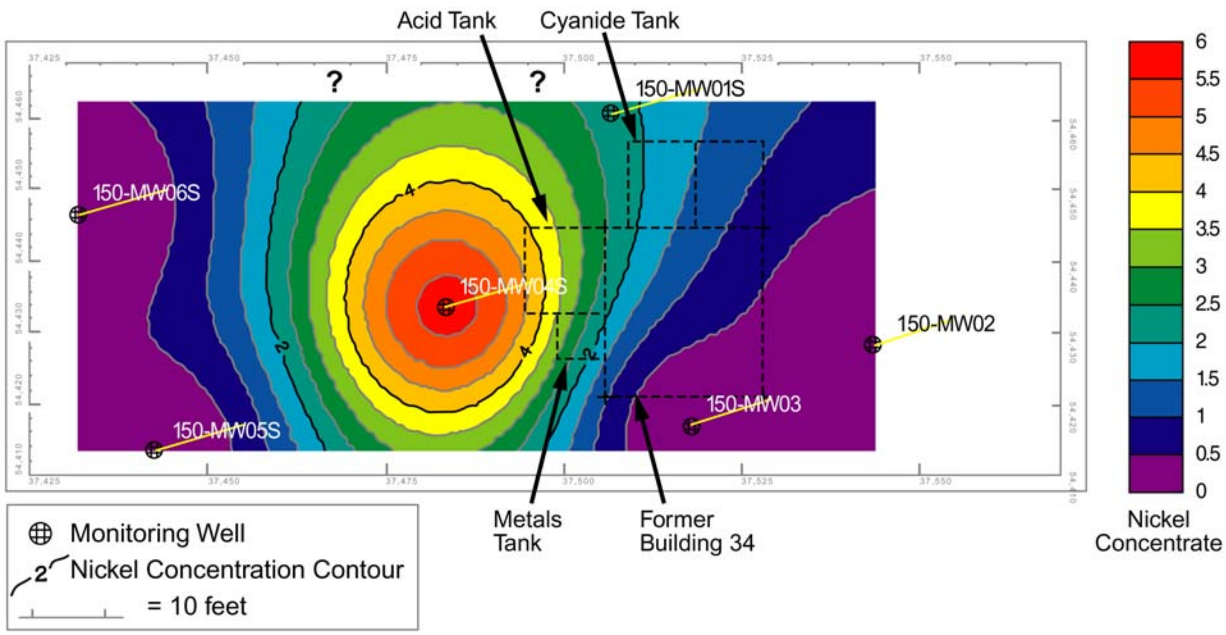


FIGURE 6.1 Isoconcentration Map of Nickel Contamination in Shallow Groundwater

7 REFERENCES

ANL: See Argonne National Laboratory.

Argonne National Laboratory, 1994, *Preliminary Assessment Report,Building 34 – Liquid Mixed Waste Treatment Facility*, Argonne National Laboratory, Argonne, Ill., Aug.

Argonne National Laboratory, 1997, *Resource Conservation and Recovery Act Facility Investigation Report, 317/319/ENE Area, Revision 1*, Argonne National Laboratory, Argonne, Ill., July.

Argonne National Laboratory, 1998, *Investigation Work Plan for Building 34 – Liquid Mixed Waste Treatment, SWMU No. 150*, Argonne National Laboratory, Argonne, Ill., Sept.

Argonne National Laboratory, 2000a, *Investigation Report for SWMU Nos. 5, 133, 136, 146, 151, and AOC-H*, Argonne National Laboratory, Argonne, Illinois, Sept.

Argonne National Laboratory, 2000b, *Argonne National Laboratory-East Site Environmental Report for Calendar Year 1999, ANL-00/2*, Argonne National Laboratory, Argonne, Ill., Sept.

ASTM: see American Society for Testing and Materials.

American Society for Testing and Materials, 1997, *D1586-83 (1992) Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils* [URL http://www.astm.org/cgi-bin/SoftCart.exe/DAT…/D1586.htm?L+mystore+nufg2225+91020892].

Bretz, J.H., 1932, *Surficial Geology of the Sag Bridge Quadrangle*, Chicago Aerial Geologic Map 13, Sag Bridge, Scale 1:24,000, Illinois State Geological Survey Division, Champaign, Ill.

EPA: See U.S. Environmental Protection Agency.

Geraghty and Miller, Inc., 1993, *Draft Phase I Hydrogeologic Assessment Work Plan*, prepared for Argonne National Laboratory, Argonne, Ill., Dec.

Hansel, A.K., and W.H. Johnson, 1987, "Ice Marginal Sedimentation in a Late Wisconsinan End Moraine Complex, Northeastern Illinois, USA," pp. 97–104 in *Tills and Glaciotectonics*, J.J.M. Van Der Meer (editor), Balkema, Rotterdam.

Hansel, A.K., and W.H. Johnson, 1993, "Fluctuations of the Lake Michigan Lobe During the Late Wisconsin Subepisode," *Sveriges Geologiska Undersokning*, Ser. Ca 81, pp. 133–144.

Hughes, G.M., et al., 1971, *Hydrogeology of Solid Waste Disposal Sites in Northeastern Illinois*, U.S. Environmental Protection Agency.

Killey, M.M., and C.B. Trask, 1989, *Geotechnical Site Investigation, 7-GeV Advanced Photon Source, Argonne National Laboratory — Final Report*, Illinois State Geological Survey, Champaign, Ill., Feb.

Killey, M.M., and C.B. Trask, 1994, *Geotechnical Site Investigation for an Advanced Photon Source at Argonne National Laboratory, Illinois*, Environmental Geology 147, Illinois State Geological Survey, Champaign, Ill.

Munie, J.L., 1999, letter from Munie (Manager, Permit Section, Bureau of Land, Illinois Environmental Protection Agency, Springfield, Ill.) to T.S. Crawford (Argonne Group Manager, U.S. Department of Energy, Argonne, Ill.), Oct. 13.

Olimpio, J.C., 1982, *Data for Wells at the Low-Level Radioactive Waste Burial Site in the Palos Forest Preserve, Illinois,* Open-File Report 82-692, U.S. Geological Survey.

Olimpio, J.C., 1984, *Low-Level Radioactive Waste Burial at the Palos Forest Preserve, Illinois: Geology and Hydrology of the Glacial Drift, as Related to the Migration of Tritium,* Water-Supply Paper 2226, U.S. Geological Survey.

U.S. Department of Agriculture, 1979, *Soil Survey of DuPage and Part of Cook Counties, Illinois*, Soil Conservation Service, May.

U.S. Environmental Protection Agency, 1986, *Test Method for Evaluating Solid Waste: Physical/Chemical Methods*, 3rd Ed., November 1986 and subsequent updates, EPA-530-SW-846, Office of Solid Waste, Washington, D.C, Sept.

U.S. Environmental Protection Agency, 1988, *Laboratory Data Validation Functional Guidelines for Evaluation of Organic Analyses*, EPA, Washington, D.C., Feb.

U.S. Environmental Protection Agency, 1997, *Index to EPA Test Methods*, pp. VI-19 – VI-21, EPA, New England Region 1 Library, Oct.

U.S. Environmental Protection Agency, 2000, *Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites,* Code of Federal Regulations, 40 CFR 192, Subpart A, July.

Willman, H.B., 1971, *Summary of Geology of the Chicago Area*, Circular 460, Illinois State Geological Survey, Champaign, Ill.

Willman, H.B., 1973, *Geology along the Illinois Waterway: A Basis for Environmental Planning*, Circular 478, Illinois State Geological Survey, Champaign, Ill.